

DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

George K. Burgess, Director

**ANNUAL REPORT OF DIRECTOR  
OF THE BUREAU OF STANDARDS  
FOR FISCAL YEAR ENDED JUNE 30, 1927**

MISCELLANEOUS PUBLICATIONS, BUREAU OF STANDARDS, No. 81



**ANNUAL REPORT**  
**OF THE**  
**DIRECTOR OF THE BUREAU OF STANDARDS**  
**TO THE**  
**SECRETARY OF COMMERCE**  
**FOR THE**  
**FISCAL YEAR ENDED JUNE 30, 1927**

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(Miscellaneous Publication No. 81)



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1 FINANCE

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## BUREAU OF STANDARDS

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DEPARTMENT OF COMMERCE,  
BUREAU OF STANDARDS,  
Washington, July 1, 1927.

HON. HERBERT HOOVER,  
*Secretary of Commerce.*

DEAR MR. SECRETARY: I submit herewith a brief report upon the work of the Bureau of Standards during the fiscal year ended June 30, 1927. The various outstanding accomplishments are grouped according to the subjects for which Congress had made specific appropriations.

### GENERAL ACTIVITIES

*Organization.*—During the past year the assistant director has acted as liaison officer on matters of aviation between the Aeronautics Branch of the Department of Commerce and the Bureau of Standards. Work formerly conducted by the Bureau of Mines transferred to the Bureau of Standards on July 1, 1926, and some of the work on lubricants formerly carried on by the automotive power plants staff have been consolidated to form a new section on friction and lubrication in the heat and power division. Several resignations caused by the bureau's inability to meet the salaries offered by industry made necessary reallocation of the work in several sections.

*Cooperation.*—Most of the bureau's work is made effective through voluntary cooperation of the State and municipal governments, scientific and professional societies, trade associations, manufacturers, and individuals who accept the findings of the bureau and incorporate them into a State law, a municipal ordinance, a dimensional standard, or a standard of quality, performance, or practice.

All such cooperation is encouraged to promote a better understanding between producer and consumer and between industries, to the end that industries shall be, so far as practicable, self-regulatory.

Many national organizations assist the bureau directly in research, standardization, and simplification, and in turn the bureau cooperates with numerous national organizations engaged in similar effort, frequently designating members of the staff to serve on committees.

The extent of these relationships is shown by the fact that at the present time the bureau is cooperating with over 200 scientific, technical, and industrial organizations. In many cases the work with any one group covers a single project, while in other cases 25 projects or more are being handled by practically every division of the bureau.

One of the most effective ways in which the bureau cooperates with American industries is through its research associate plan, referred to in past annual reports. At the close of the fiscal year there were 63 of these associates stationed at the bureau, representing 38 industries and associations.

*Personnel matters.*—The regular staff at the close of the fiscal year numbered 850 employees. In addition there were 63 employees assigned to the bureau under the research associate plan and 11 miscellaneous assignments, including guests and details from other branches of the Government, making a grand total of 924 persons.

The turnover was 24.2 per cent, and although there were 449 promotions the average salary (\$2,210) decreased by \$22.

The status of the personnel shows an increase of 87 employees as compared with last year. However, 52 of these were added as the result of reallocation of work within the Government service. The employees engaged in operating the mechanical plant were transferred back to the bureau's rolls, and the ceramic laboratory at Columbus, Ohio, and the oil-testing work were transferred from the Bureau of Mines.

*Visiting committee.*—This committee, established by law "to visit the bureau at least once a year and report to the Secretary of Commerce upon the efficiency of its scientific work and the condition of its equipment," met at the bureau twice during the past year and has given particular attention to the financial needs of the bureau to meet the ever-increasing demands from the public and Government for testing and research, as embraced in two reports to the Secretary of Commerce. The present personnel of the committee is S. W. Stratton, Gano Dunn, William F. Durand, W. R. Whitney, and John R. Freeman.

*International relations.*—The usual close cooperation between the national standardizing laboratories of other countries and the Bureau of Standards has been maintained. Negotiations have been carried on for the improvement of standards on which electrical, photometric, and radio measurements depend. The International Committee on Weights and Measures has proposed a chain of comparative measurements, including the national laboratories of Germany, France, Great Britain, Japan, and the United States, and the bureau has prepared standards of voltage and resistance for shipment to Japan and Great Britain. Standards of candlepower representing the newer types of lamps have also been prepared for exchange with the national laboratories in Europe. Comparisons of radio-frequency have been made with several of these and other laboratories by means of quartz piezooscillators which have been shipped from one laboratory to another.

In September the International Conference on Weights and Measures will meet in Paris. This conference meets at least once in six years, and outstanding problems in metrology are discussed. The bureau expects to present several important questions for consideration in the fields of metrology, optics, and electricity.

The second Pan American standardization conference was held in Washington on May 9 to 11. The last day's session took place at the Bureau of Standards, and a beginning was made in the grading of commodities of Latin-American origin.

*Weights and measures conference.*—The Twentieth National Conference on Weights and Measures was held on May 24 to 27 and was attended by 225 persons, of whom 102 were official representatives from 22 States, Porto Rico, and the District of Columbia.



Among the important constructive actions taken by the conference may be mentioned the adoption of a code of specifications and tolerances for bottles for the sale of lubricating oil, modification of specifications for liquid measuring devices, completion of important preliminary work on specifications and tolerances for grease-dispensing devices, adoption of recommendation for sale of ice cream on volume basis with regulation of "overrun," and adoption of amendments to model State weights and measures laws establishing ton of 2,000 pounds for all commodities and cord of 128 cubic feet for measurement of firewood.

*State utility commission engineers' conference.*—The fifth annual conference of State utility commission engineers was held at the bureau June 2 and 3 and was attended by representatives of 16 State commissions and one Province of Canada. The program included discussion of street railway, electric, and gas service, as well as problems in the determination of depreciation and the theory of rate schedules.

*American Engineering Standards Committee.*—Cooperation has been continued with the American Engineering Standards Committee. The bureau is sponsor for 13 standardization projects and is represented on 73 committees having for their object the formulation of "American standards."

*National Screw Thread Commission.*—The standards established by the National Screw Thread Commission provide for two series of threads, a coarse and a fine, and for four classes of fit, ranging from the loose fit for very rough work to the close fit for work of the highest precision. Dimensions and tolerances for each thread series and class of fit are included in a report issued in 1924. Specifications and tolerances for pipe threads, fire-hose threads, and small-hose threads are also included.

Certain details of the 1924 report have been perfected, and several new sections on special threads have been added. The commission has also cooperated with the standardization committee of the American Petroleum Institute in the standardization of drilling-tool joints, pumping equipment and gauges, and with the Federal Specifications Board in the standardization of machine screws, bolts, and nuts to be purchased by the Federal Government.

Much time and attention are now being given to the important task of specifying dimensions of threading tools and limit gauges which will insure that a product within these limits will result when the tools are properly used under normal working conditions. This work is in cooperation with large manufacturers and users of threading tools.

*Federal Specifications Board.*—The board has been in existence for nearly six years and has just promulgated the five hundredth purchase specification. The use of these specifications is mandatory on all Government activities by Executive order. These specifications are being used more and more by State and municipal governments, institutional bodies, and by industry. Much of the research and experimental work necessary in connection with the formulation of the Federal Specifications Board specifications is done by the Bureau of Standards.

*Facilitating the use of specifications.*—The inability of most purchasers to test goods which they buy has prevented a more widespread use of specifications. The "certification plan" has been introduced to eliminate this disadvantage.

Lists have been compiled of manufacturers who will certify to purchasers that goods delivered comply with certain specifications. These lists will be forwarded upon request; 75 commodities have been covered to date.

A list of commercial and college laboratories which will make tests to determine whether deliveries comply with specifications has been published.

*Relations to Government departments.*—The bureau is authorized to receive funds for specific research projects from other departments, and in pursuance of this policy in the past year the bureau has received \$295,000 for the support of 44 projects representing work for nine Government establishments. In addition, the bureau does a great deal of consulting, specification, and testing work for various branches of the Government.

*Publicity.*—In addition to its regular official publications, of which 118 were issued during 1927, the monthly Technical News Bulletin has been mailed as heretofore. The number of pages has been increased, and this bulletin is on a self-supporting basis. More than 200 papers have been published in outside technical journals. There have also been released to the press about 250 short accounts of interesting achievements, together with many photographs illustrating the bureau's work. These news items serve as nontechnical progress reports on the activities of the bureau to the taxpayers of the country.

There was also issued the first annual number of the Standards Yearbook, giving a summary of standardization activities in the United States for the past year.

*Tests completed.*—An itemized statement of tests completed is given in the following table:

*Numbers of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1927*

Kind of instrument or material, class of test, or nature of service rendered	Number of test items for—			Total number of test items	Number of determinations	Fee value
	Public	Government departments and State institutions	Bureau of Standards			
Electrical standards, instruments, and materials.....	1, 247	497	220	1, 964	3, 927	\$13, 732.89
Electric batteries.....		1, 537		1, 537	2, 944	9, 769.50
Electric lamps and lighting equipment.....	201	2, 691	451	3, 343	3, 541	17, 564.12
Length-measuring devices.....	172	168	2	342	2, 113	2, 063.90
Gauges and gauge steels.....	1, 540	479	1, 055	3, 074	11, 854	2, 478.00
Miscellaneous dimensional determinations.....		1, 361	87	3, 566	14, 052	6, 411.90
Weights and balances.....	5, 942	1, 143	533	7, 618	16, 201	4, 893.40
Scales.....		979		979	25, 352	42, 990.00
Timepieces.....	427	10	18	455	5, 871	912.00

<sup>1</sup> In addition the bureau inspected 1,216,751 incandescent lamps at various factories for other branches of the Government.

<sup>2</sup> Includes fee value of \$3,196.12 for lamps inspected at factories.

Numbers of test items, determinations, and fee value for tests completed during the fiscal year ended June 30, 1927—Continued

Kind of instrument or material, class of test, or nature of service rendered	Number of test items for—			Total number of test items	Number of determinations	Fee value
	Public	Government departments and State institutions	Bureau of Standards			
Volumetric apparatus.....	6,932	4,949	154	12,035	23,046	\$7,657.00
Hydrometers.....	627	128	5	760	2,327	1,149.45
Density determinations, etc.....	59	7	294	360	560	536.00
Laboratory thermometers.....	2,161	825	235	3,221	17,447	6,309.55
Clinical thermometers.....	34,950	28,819	-----	63,769	255,076	5,043.41
Pyrometers, calorimeters, etc.....	167	60	124	351	3,289	3,703.74
Insulating materials.....	32	37	16	85	141	620.00
Fire-resisting materials.....	17	44	-----	61	145	4,863.00
Fuels and lubricants.....	60	1,693	160	1,913	12,295	18,530.00
Automotive equipment, etc.....	175	67	24	266	903	1,136.50
Optical instruments and materials.....	319	506	195	1,020	2,542	5,095.60
Carbohydrates.....	17	1,897	-----	1,914	2,906	3,194.50
Radioactive materials.....	523	31	-----	554	564	3,493.00
Engineering instruments and appliances.....	128	640	54	822	956	10,758.50
Aeronautic instruments.....	21	229	14	264	750	3,686.00
Aerodynamic tests of models.....	12	5	10	27	96	1,452.00
Physical properties of engineering materials.....	373	2,292	144	2,809	5,103	15,517.17
Sound producing and measuring instruments.....	15	51	27	93	117	1,398.50
Making of special castings.....	-----	58	262	320	989	2,613.68
Fusible boiler plugs.....	-----	366	-----	366	731	1,827.50
Metallographic examinations.....	-----	381	99	480	682	2,373.36
Miscellaneous metallurgical tests.....	-----	377	615	992	2,823	6,460.82
Pottery and chinaware.....	5	212	10	227	780	1,523.00
Glass.....	-----	22	18	40	120	455.00
Refractories and heavy clay products.....	4	62	81	147	1,076	2,860.00
Cement, concreting materials, lime, etc.....	36	8,394	125	8,555	28,435	112,838.33
Stone and sand-lime brick.....	-----	48	4	52	732	369.25
Miscellaneous ceramic materials.....	3	1,634	87	1,724	2,159	8,254.50
Rubber.....	-----	1,521	376	1,897	12,160	28,218.26
Textiles.....	-----	6,298	211	6,509	14,182	24,362.00
Paper.....	47	2,036	160	2,243	6,565	16,008.00
Leather.....	13	218	1	232	1,028	1,627.00
Paint, varnish, and bituminous materials.....	-----	1,170	19	1,189	9,687	21,020.79
Chemical analysis of metals.....	1	465	354	820	3,526	11,982.80
Chemical tests of miscellaneous materials.....	-----	999	108	1,107	3,909	9,965.60
Distribution of standard samples.....	5,830	630	20	6,480	24	13,545.50
Total.....	64,174	76,036	6,372	146,582	3 503,726	3 461,265.02

<sup>3</sup> Of these totals, 214,826 determinations were for the public, fee value, \$60,228.73; 269,367 determinations were for the Government departments and State institutions, fee value, \$357,374.64; 19,533 determinations were for the bureau, fee value, \$43,161.65. The number of test items and determinations necessary in connection with the bureau's own work of research and standardization, with the resulting fee values, are not included in these totals.

### SALARIES (\$567,320)

This fund provides for personal services of administration and operation; the establishment, upkeep, and comparison of standards; the development of methods of test, as well as most of the testing; and for the determination of fundamental constants of importance in physics, chemistry, engineering, and technology not otherwise provided for.

*Basic electrical units and standards.*—Progress has been made in checking the commonly used values of the electrical units by reference to the fundamental definitions. The need for this work has become more urgent because the International Committee on Weights and Measures is now taking up the problem of establishing and

maintaining authoritative international values for the units. Coils and related apparatus must be constructed with a very high degree of mechanical precision in such form that their electrical properties can be calculated and these calculated values compared with those found by electrical measurements. One part of this work on the induction of a helix made with wire of any section has been published, and another paper on absolute measurements of capacitance by Maxwell's method is in press.

*Constant of gravitation.*—After four years of work with improved apparatus the first results of the redetermination of the Newtonian constant of gravitation were obtained during the past year. Five values have been obtained—6.661, 6.661, 6.667, 6.667, and 6.664—giving as a mean 6.664 by  $10^{-8}$  cm. <sup>3</sup>/gm. sec.<sup>2</sup>, a result ten times more accurate than hitherto obtained.

*Standard of planeness.*—Three standards of planeness have been made of clear fused quartz, a material chosen because its distortion arising from temperature irregularities is about one-fifteenth that of glass. They are in the form of disks about 10 inches in diameter and  $1\frac{1}{2}$  inches thick, being rigid enough to rest on three points without appreciable distortion. The workmanship on these flats is of such a high grade that all three surfaces depart from planeness by less than one-hundredth of a light wave length—less than two ten-millionths of an inch.

*Airplane lenses.*—In order to select the best lenses to be used in aerial mapping complete tests were made on 74 lenses for the Army Air Service. Special attention was paid to the determination of the amount of distortion present in the photograph.

*High precision method of lens testing.*—The well-known Hartmann test has been modified to permit the interpretation of the aberrations of the lens, in terms of wave length, by means of the diffraction effects of the apertures of the Hartmann diaphragm. This method, which readily determines quantitatively even the effect of striae, differs from other interferometric methods in that it can be applied to large telescopes without the necessity of having large auxiliary optical flats.

*Filters for photographic sensitometry, colorimetry, and photometry.*—A series of liquid filters, reproducible from specification, has been developed for converting to average noon sunlight the energy distribution of incandescent lamps having any "color temperature" between  $2,300^{\circ}$  and  $4,000^{\circ}$  absolute. Important by-products of this investigation are (a) the application of these same filters to the measurement of color temperature and intensity of incandescent lamps and (b) the development of a similar group of filters for converting the color of a lamp operated at  $2,848^{\circ}$  (the bureau's standard) to any color temperature between  $3,000^{\circ}$  and  $10,000^{\circ}$  absolute.

*Therapeutic light sources.*—An investigation of the radiation from the carbon arc under different conditions of operation was conducted in cooperation with the National Carbon Co. Data were obtained on the ultra-violet component of the radiation using different kinds and sizes of carbon electrodes, different kinds of cores for these, large and small electric currents; also with direct current and alternating current potentials.

*Windows for transmitting the "vitalizing" rays of sunlight.*—After investigating the ultra-violet transmission characteristics of numerous substitutes for window glass it was found that the most widely known of the new glasses transmits about 50 per cent of the vitalizing rays of sunlight which are excluded by ordinary window glass, and a more recent production shows about 92 per cent transmission. Glass substitutes, consisting of a cellulose product on wire mesh, fall somewhat below 50 per cent.

*Revision of solar spectrum wave lengths.*—In cooperation with the Allegheny Observatory wave lengths of 400 lines in the yellow, orange, and red portions of the spectrum have been measured and published. Comparison of these solar values with laboratory values shows a red displacement of the solar lines as a function of their intensity but in which the displacement appears to be somewhat smaller for the longer than for the shorter wave lengths. If it is assumed that the intensity scale for the longer waves is the same as for the shorter, these results continue in contradiction to the explanation given by the Einstein gravitation theory.

*Density of pure iron and carbon steels.*—The densities of pure iron and of various carbon steels have been determined. The average density of pure iron is 7.864 grams per cubic centimeter. Carbon steels as hot-rolled show a gradual decrease in density with increasing carbon content up to about 1.3 per cent and lie on or close to the straight line:

$$\text{Density} = 7.855 - .032 C$$

where  $C$  is the percentage of carbon.

Carbon steels as annealed show a gradual decrease in density with increasing carbon content up to about 1.4 per cent, and the values lie on or close to the straight line:

$$\text{Density} = 7.860 - .04 C$$

where  $C$  is the percentage of carbon.

The density of carbon steels containing up to about 1.3 per cent carbon decreases upon quenching, due to the formation of martensite. The magnitude of this decrease rises with increasing carbon content, reaching a maximum at about 1 per cent carbon and then falls off slightly. Upon tempering the quenched steels they gradually increase in density. A decrease in density was noted in the hypereutectoid steels, when tempered at 225° C., due to the tempering of retained austenite. Upon tempering about 225° C. the density of all samples increased, ultimately approaching the density of the annealed material when tempered at 600° C. The greatest rate of increase of density was noted upon tempering at 300° C., the rate then gradually falling off practically to zero at 600° C.

*Properties of pure metals.*—The fundamental properties of pure thorium and pure nickel have been investigated, so that the bureau is prepared to give information on the constants of these important metals. The melting of nickel of purity hitherto unreached, by methods which avoid contamination, and the working of it into form suitable for determining its constants have been successfully accomplished. Special refractories have been prepared for melting the pure metals. Methods for obtaining precision measurements of the

lattice constants of thorium by the X-ray spectrograph have also been developed. The metallographic properties of pure iron have been studied in cooperation with a research fellow of the Swedish-American Foundation.

*Metallurgical testing, research, and service for the Government.*—Testing of metals and allied materials for other branches of the Government included routine tests of 341 fusible plugs for the Steamboat Inspection Service and research on factors affecting their possible failure to function in service; examination of failed propellers for the Bureau of Aeronautics of the Navy; tests of iron pipe for the repair of the White House; study of air-hardening rivets for armored tanks, at the request of the Ordnance Department of the Army; testing of foundry sands for the Panama Canal and the Washington Navy Yard; and a wide range of miscellaneous tests. Advice has been given the Department of Justice and the Federal Trade Commission on metallic products. Work on tarnish-resisting silver alloys for the Bureau of Mines has been completed and published. Metallurgical work has been done on storage-battery alloys for the Navy.

*Wear of metals.*—The fundamental properties of metals used for gauges affect their resistance to wear. Special apparatus has been constructed to study the wear resistance of gauges in the laboratory. Chromium-plated gauges and special steel gauges given a nitride coating by treatment in ammonia have been found markedly superior to ordinary gauges in resisting wear. This phase of the wear problem is completed, one report has been issued, and a second is ready for publication.

*Elastic hysteresis research.*—A technologic paper on the statical hysteresis in the flexure of bars was issued, in which a new fundamental constant has been shown to exist, called the statical hysteresis modulus. Experiments on the statical hysteresis in cycles of equal load range have greatly widened the applicability of the law given in the above paper. A theoretical relation has been deduced between the damping of a tuning fork in air and the statical hysteresis modulus of the material of which the tuning fork is made.

*Magnetic testing methods.*—A new edition of the circular on magnetic testing has been issued and special studies of commercial testing methods have been reported in a paper on determination of the magnetic induction in sheet steel. The applicability of magnetic measurements as an indication of mechanical properties of materials has been treated in papers on nondestructive testing of wire hoisting rope by magnetic analysis and on the magnetic reluctivity relationship.

*Standards of candlepower.*—The bureau several years ago established provisional standard values for the newer types of electric lamps, but no international agreement has yet been reached on candlepower standards of these types or on a general method of making photometric measurements when the lights to be measured differ in color. Comparisons have been made both with laboratories in this country and with national laboratories abroad. When completed, these comparisons will serve to determine the constancy with which the basic carbon standards have been maintained in the different countries and will indicate the degree of agreement attainable in the establishment of the newer standards by the various methods available.

*Lamp-testing methods.*—The general introduction of the new types of inside-frosted electric lamps has required changes in testing procedure. The specifications for lamps have been revised and the testing methods used have been published.

*Time of breakdown of paint.*—Progress was made on a quantitative method of determining the time of breakdown of paint and similar coatings, as well as a study of accelerated tests to simulate weather decay.

*Changes in rubber compounds.*—An investigation of the effect of added fatty acids upon the tensile properties of rubber compounds was completed, and progress was made on a study of the changes caused in rubber by heat, light, and oxidation, and the effect of adding antioxidants.

*Impurities in reagents.*—The bureau's critical study of methods for detecting and determining small amounts of impurities in reagent chemicals was continued. This work formed an important contribution to the specifications for a number of chemicals prepared by the American Chemical Society.

*Increasing speed of zinc plating.*—A study of acid zinc-plating baths showed that by appropriate additions the conductivity and permissible rate of deposition can be greatly increased.

*Apparatus for analyzing breath.*—A thermal conductivity apparatus for determining both carbon dioxide and oxygen in respired air has been developed. Because of the rapidity with which determinations can be made, physicians are very enthusiastic about the method and anticipate its extensive adoption in hospital practice.

*Weights and measures.*—This work included investigations of steel tapes to determine thermal expansion and of Young's modulus and sag correction; a study of watches equipped with invar balances and elinvar hairsprings; the effect of humidity changes on the constancy of lacquered analytical weights; density changes in glass and in steel caused by changes in heat treatment; the application of the photo-electric cell to the measurement of short-time intervals; the thermal expansion of creosote oils; the density of copper; and the density and weight per gallon of denatured alcohol.

*Variability in weights caused by changes in atmospheric humidity.*—A study of variations in gold-plated and lacquered screw-knob weights under relative humidities of 30 and 70 per cent shows that (1) changes in the weights are sometimes of great importance—occasionally as large as 2 or 3 mg. on the sum of the weights in sets from 1 to 50 or 100 g.; (2) in general, gold-plated weights showed greater variability than lacquered weights, apparently because the plating salts from the electroplating solution had not been wholly removed from the cavity under the knob. These weights can be improved by thoroughly washing out these salts, and manufacturers who have adopted this precaution are now furnishing much more stable weights.

*Orifice-meter investigation.*—The particular object of this year's cooperative work with the Natural Gas Association has been a study of the effects of various combinations of bends, regulators, valves, and straightening veins upon the indications of orifice meters. Very consistent and instructive results were obtained, which showed some previous ideas on orifice-meter behavior to be erroneous.

*Viscosity and consistency measurement.*—A diagram has been devised for estimating the viscosity of petroleum oils at one temperature when known at another. For some materials, such as oils containing soap, the usual methods of measuring viscosity do not apply. A new type of apparatus suited for this purpose, known as the "burette consistometer," has been investigated and found to be both accurate and rapid in operation.

*Thermal properties of petroleum products.*—A thorough review of the literature and of data obtained at the bureau indicates that certain properties of petroleum products—namely, coefficient of expansion, heat of combustion, specific heat, latent heat of vaporization, and perhaps thermal conductivity—can be calculated within close limits if the density of the oil is known, as set forth in a paper before the American Chemical Society.

*Platinum resistance thermometry.*—An investigation of platinum-resistance thermometers has been undertaken to aid in the standardization of a low-temperature platinum resistance scale of temperatures to  $-183^{\circ}$  C. as a part of a cooperative program between the bureau and the national laboratories of England, France, Germany, and the Netherlands for uniformity in temperature measurements.

*Specification for automobile tires.*—The Government purchases of tire equipment amount to approximately \$1,500,000 a year, with a rapidly increasing proportion of balloon and truck tires. As a result of tire tests during the past three years the bureau, with the cooperation of the Rubber Association of America, has obtained sufficient data to revise the Federal specification for automobile tires, so as to include balloon tires and truck tires. In this specification an endurance test simulating road service has been provided for each size and type of tire.

*Construction of apparatus for laboratory and other purposes.*—The instrument shops, machine shops, pattern and woodworking shops, glass-blowing shop, tool room, and construction storeroom took care of all demands made upon them for the construction of instruments, apparatus, and their installation in the laboratories, as well as the preparation of all routine samples submitted for tests and the preparation of the standard steel, cast iron, and various alloy steels used as standard samples.

Some of the more important instruments and apparatus constructed during the year are: Diffuse reflectometer, optical lens centering apparatus, 10 small laboratory telescopes, interferometer, pendulum apparatus, furnace for expansivity testing, sand-blasting machine for the numbering of clinical thermometers, proving rings for calibration of testing machine, ionization chamber, graduated track for Weber photometer, three radiobeacon goniometers, magnetic comparator for fatigue machine, spherometer, vibration galvanometer, commutator and switch for platinum-resistance thermometer bridge, camera for spherical aberration tests, radiobeacon interlocking switch, installation of grating mounting in constant-temperature room of spectroscopic laboratory, electric furnace, wear-test machine, alpha ray counting apparatus for exhibit at New York Industrial Museum, galvanometer for Maxwell bridge, variable mutual inductance apparatus, two 500-microhenry self-inductances, one telescope for absolute electrometer, one 10 and one 20 inch strain gauge, one



resistance box (0.01 ohm and 10,000 ohms), one resistance box (100 to 10,000 ohms), one rotating sample holder, X-ray tube holder, and hardness testing apparatus.

*Operation and maintenance of buildings.*—The employees engaged in plant operation and maintenance are divided into three principal groups—namely, power plant, guard, and janitorial groups. The first group operates and maintains the power plant which supplies heat, light, power, and other miscellaneous service; the second group polices the bureau's property; and the third group does the routine cleaning work within the buildings. The functions were performed as usual.

#### EQUIPMENT (\$88,000)

*General equipment.*—The usual purchases of apparatus and supplies necessary to maintain the bureau's laboratories in up-to-date and efficient condition have been made. A considerable amount of special equipment for the radio section has been purchased for use in connection with experiments on radiobeacons and radio transmission between planes and the ground.

*Supercalender stack.*—A new supercalender stack was purchased for the experimental paper mill. This machine is fitted for five rolls, 27 inches wide, and is driven by a variable-speed electric motor, giving roll speeds of 40 to 300 feet per minute.

*Dead weight testing machine.*—A dead weight vertical testing machine of 100,000 pounds capacity, built by A. H. Emery, jr., in accordance with suggestions made by the bureau, has been secured. It will be used primarily in the accurate calibration of proving rings, which in turn will be used for the calibration of service testing machines in the field. The 10,000-pound weights are applied to the ring with the aid of a hydraulic press so that the load may be applied either in tension or in compression in 10,000-pound increments up to a maximum of 100,000 pounds.

*New constant-temperature room.*—The new equipment for graduating and testing circles and for comparing linear scales will be installed in a new basement room which has just been completed.

#### GENERAL EXPENSES (\$68,355)

*Upkeep of mechanical plant.*—The usual maintenance work and repairs have been carried on. A 25-ton refrigerating plant was installed in the industrial building. New commutators were mounted on fan motors for the bureau's heating system.

*Electrical construction and repairs.*—The work included the usual maintenance and construction, as well as some extensions to the electrical service carrying various voltages. Several large pieces of equipment were connected up, such as the new supercalender in the paper section, large electromagnet in the new spectroscopic laboratory, 100-horsepower rotary exhausters in the altitude laboratory, and a 200-horsepower motor for a large air compressor.

*Plumbing and steamfitting.*—Work required by several extensions of gas, air, vacuum, water, steam, and refrigeration lines was performed. Special installations included a large air compressor, exhaust pumps, and equipment in the semicommercial sugar plant.

*Miscellaneous repairs and alterations.*—This work included building foundations for a variety of equipment, relining boiler settings, and several alterations to buildings such as the excavation for the new spectroscopic laboratory and the new room for precision length measurements.

*Library books.*—The number of volumes accessioned this year was 1,552, making the total number of accessioned volumes 30,818, as compared with 29,362 last year; 730 scientific and technical periodicals are received by the bureau's library.

*Travel.*—Provision was made for necessary travel to consult with experts at meetings of scientific and technical societies, travel of members of the bureau's visiting committee, and travel in foreign countries on cooperative work of the bureau with other national standardizing institutions.

*Contingent expenses.*—Part of the contingent expenses of the bureau and of the Department of Commerce as a whole have also been provided for.

#### IMPROVEMENT AND CARE OF GROUNDS (\$12,000)

*Improvement of grounds.*—Considerable progress has been made in the improvement of the grounds, particularly in the plot lying along Connecticut Avenue. This part of the property has been graded and planted and is now in a fairly satisfactory condition. A new entrance walk has been completed which adds greatly to the comfort and convenience of the employees.

#### TESTING STRUCTURAL MATERIALS (\$230,000)

*Building codes.*—The building code committee published its Recommended Building Code Requirements for Unit Working Stresses in Building Materials and has made substantial progress on its report on fire-resistive construction. At least 85 municipalities throughout the country have used recommendations of the committee in code revisions. The committee suffered a heavy loss in the death of its chairman, Ira H. Woolson, on May 8.

*City planning and zoning.*—The Standard State City Planning Enabling Act was completed in February by the Advisory Committee on City Planning and Zoning and within three months was utilized in laws enacted in three States. New editions of the Standard State Zoning Enabling Act (which has now been utilized in the laws of at least 28 States), a Zoning Primer, and a City Planning Primer were issued and reports on zoning progress have been issued from time to time.

*Standard State Mechanics' Lien Act Committee.*—The voluntary committee, which is drafting a recommended standard State mechanics' lien act, circulated a preliminary tentative draft and is now perfecting it with the aid of the comments and criticisms.

*Statistical work.*—Monthly prices for 24 building material items as paid by contractors in about 50 cities have been obtained, issued regularly, and republished in a number of trade papers. They are also used in compiling index numbers of the price of materials for small frame and brick houses. Current statistics on building activity, building costs, production, consumption, and stocks on hand of

the principal building materials were printed regularly in the Survey of Current Business and its advance releases.

*Cooperation with Government and private agencies on building and housing problems.*—Cooperation was continued with Federal, State, and local governmental agencies, and with private organizations concerned in building and housing. Material relating to construction was furnished for several publications of the Bureau of Foreign and Domestic Commerce, a number of drafts of building codes were reviewed, and problems relating to city planning and zoning, building costs, and home ownership were taken up in conjunction with such groups as Better Homes in America, the American Construction Council, the American Civic Association, and bodies representing architects, engineers, and business and labor groups connected with construction.

*Structural steels high in silicon.*—A technologic paper has been issued describing the properties of structural steel high in silicon which has an exceptionally high yield point.

*Standard finishes for builders' hardware.*—In cooperation with manufacturers the bureau established in 1924 a simplified and standardized line of 25 hardware finishes. Sixteen of these are fixed as regards color by the composition of the metal. The remaining nine, so-called "oxidized" finishes, are dependent upon the process employed in the finishing room. Unfortunately they also tend to change color slowly with time, particularly when exposed to strong light and humidity. Twenty-five new sets of these nine finishes were distributed to interested manufacturers for use as reference standards. At the same time a spectrophotometric study was made of each finish, including the determination of the dominant wave length, purity, and reflective value. The color characteristics of these standard finishes have thus been established independently of any material standard.

*Vitreous china plumbing fixtures.*—Through the hearty cooperation of the manufacturers the standardization of vitreous china plumbing fixtures has made steady progress. This has included simplification, the development of a standard nomenclature, grading rules, and dimensional standards. Forty thousand copies of the pamphlet embodying the above standards are being distributed by the manufacturers to architects and plumbers.

*Refractory bricks and clays.*—Tests of 17 brands of clay refractories and of each individual material used in their manufacture show a wide range in thermal expansion, elasticity, and mechanical strength values, although the pliability, or maximum elongation at rupture, did not vary greatly from an average of about 0.04 per cent. The relative qualities of the various materials in any one mixture may have an important bearing on the properties of the product irrespective of the method of manufacture. A method has been developed by which it may be possible to estimate quite closely the relative resistance of sagger clays to spalling in service. At the Columbus station cooperative work with the American Society of Mechanical Engineers has been continued in a study of the cause and control of brick failure in boiler settings.

*Cast iron for enameling purposes.*—A new method of distinguishing between irons, with respect to their tendency to produce blistered

ware when enameled, has been developed. The range of conditions under which an iron can be enameled without blisters determines whether it is good or poor. This method of "range finding," besides being an important step in the solution of the problem of differentiating between enameling irons, helps to eliminate blisters in the manufacturer's output. Preheating the iron before coating it with enamel helps to eliminate blisters, since the gas has a chance to evolve at a temperature below the fusion point of the enamel.

*Maintenance of interior marble.*—This cooperative investigation with the National Association of Marble Dealers has been completed. A paper now being printed relates to methods and preparations for cleaning interior marble, means of treating stains, and preservation of the natural appearance.

*Methods of cleaning limestone masonry.*—An apparatus which employs high-pressure steam and water has been given several practical trials and appears to meet the requirement of cleaning without injury to the stone.

*Stone preservatives.*—Exposure tests in progress for six years indicate that the only type of treatment which will endure for this period is the paraffin type.

*Frost action.*—Frost tests indicate that in severe climates poor grades of limestone and sandstone will probably show extensive decay in 25 years, while other grades might last three or four centuries. Efflorescence may produce more rapid deterioration than frost, and decay of stonework within two or three years after a building is erected can usually be attributed to this cause.

*Sound-absorbing gypsum plaster.*—Ninety per cent of the acoustical defects of auditoriums, theaters, and churches may be remedied by a sound-absorbing plaster. A gypsum plaster composed of 2 parts of volcanic tufa, 1 part sand, and 1 part of calcined gypsum and containing 2 per cent by weight of the calcined gypsum of a mixture of calcium carbonate and potassium alum in molecular proportions with retarder has been found to have the sound-absorbing properties desired.

*Method of analysis of hydrated lime.*—There is no chemical method of analysis of hydrated lime which gives information relative to the  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Ca(OH)}_2$ ,  $\text{Mg(OH)}_2$ , and  $\text{CaCO}_3$  contents when all are present. A thermochemical method of analysis has been developed. The sample is heated at succeeding temperatures for definite periods of time, and the loss in weight is plotted against temperature. Breaks occur in the curve indicating the dissociation of the  $\text{Mg(OH)}_2$ ,  $\text{Ca(OH)}_2$ , and  $\text{CaCO}_3$ , and the loss in weight due to the decomposition of each constituent may be obtained. From these data the percentages of the compounds may be calculated.

*Adhesion of mortar to sand-lime brick.*—Tests on adhesion of mortar to sand-lime brick show that, so far as adhesion is concerned, a brick which absorbs some water from the mortar is more desirable than a nonabsorptive brick. Brick which absorb water quite rapidly should have their rate of absorption reduced by wetting. Wetting brick having a low rate of absorption decreases the adhesion. Bricks of one make may vary so much in rate of absorption that the adhesion of the mortar is affected more by this than by changes in mortar composition.

*Strength of hollow-tile and concrete slabs.*—Tests of 102 beams representing different types of hollow-tile and joist-floor construction show that the value of the tile in resisting shearing stresses is a function of their compressive strength.

*Strength of brickwork.*—One hundred and fifty-nine walls, 9 feet high and 6 feet long, and 130 smaller masonry specimens have been tested. Data have been secured on the factors which affect the strength of both solid and hollow walls of brick.

*Strength of hollow-tile walls.*—An investigation of the compressive and transverse strength of walls built of a specially designed hollow tile indicated that mortar and workmanship are the most important factors affecting the strength of these walls.

*Concrete mine stoppings.*—Tests of 12 slabs show approximately equal stresses under static pressures and under pressures produced by explosions.

*Stevenson Creek experimental dam.*—The Stevenson Creek experimental dam, erected solely for test purposes under the supervision of a national committee, has been built to a height of 60 feet, and the tests at this height have been completed. During the studies of the data progress reports have been issued which indicate that a reduction in the cost of arch dams may be effected by applying the results of this work.

*Durability of aggregate.*—The necessary apparatus has been assembled and 36 samples of aggregate collected from all parts of the United States, representing granites, trap rocks, sandstones, limestones, slags, and miscellaneous varieties of gravels. All samples have been carefully graded, and durability tests are now in progress involving several different treatments. It has been noted that the boiling and drying treatment and  $\text{Na}_2\text{SO}_4$  treatment are the most severe and are apparently equally effective.

Limestones are apparently disintegrating more rapidly than other aggregates. The gravels contain so many varieties of stone that disintegrated particles are found in almost all of them, but by far the greater number are sound. Granites have not been affected and only occasional pieces of trap. Sandstone and slags have shown signs of breaking up.

*Methods of testing cement.*—In cooperation with the American Society for Testing Materials, comparison tests were made on 32 brands of cement, trying a proposed method of pouring a neat cement briquet, to replace the mortar briquet as a test specimen for cement. The new type of specimen has advantages over the old, but the preparation must be adjusted to allow for variations in the normal consistency requirements. A study of the linear changes of neat cement specimens—one with normal consistency, the other with 42 per cent excess water—showed various contractions in volume during setting, ranging from no change to 0.09 per cent, the values for the individual cements scattering between these limits.

*Inspection of cement.*—During the year there have been tested and shipped under bureau supervision 683,362 barrels of cement. Because of the increased shipments of small quantities of cement at widely separated points, especially in the Northampton district, the testing and shipping of a slightly smaller amount of cement than last year has required a greater number of inspector hours.

Comparison tests on samples of three identical cements have been made each month at the Washington and the three branch laboratories. This has resulted in a considerable improvement in the uniformity of results obtained at the four laboratories. A device to measure the pressure applied in making mortar briquets has been installed and has helped to secure uniform results. Fifty No. 200 sieves were tested, and 427 standard fineness samples of cement were distributed.

*Branch laboratories.*—The bureau maintains three branch laboratories. The Northampton (Pa.) laboratory is used exclusively for the inspection and testing of cement and being advantageously situated in the Lehigh Valley cement-producing district, supervises the major portion of the Government purchases for tested cement. The Denver laboratory tests cement in the territory west of the Mississippi River and is engaged in the study of available concrete aggregates used by the Reclamation Service. The San Francisco laboratory tests cement and miscellaneous materials purchased by the Government on the western coast.

#### TESTING MACHINES (\$38,000)

*Calibration of testing machines.*—The proving ring for calibrating testing machines in industrial plants has been further developed, so as to provide a reliable instrument for transferring loads applied by the dead weight testing machine (see "Equipment") to the machine under calibration. Proving rings having capacities of 10,000 and 100,000 pounds are now nearing completion.

*Compressive strength of brickwork.*—This investigation, in cooperation with the Common Brick Manufacturers' Association, has included the construction and testing of 168 brick walls, 6 feet wide, 9 feet high, and 8 or 12 inches thick. In addition, similar tests have been made on approximately 100 wallettes. The variable factors include brick, mortar, type of construction, effect of wetting, and workmanship. The laboratory work is nearing completion, and the results are being prepared for publication.

*Welded rails.*—A series of repeated impact tests on welded rail joints in cooperation with the American Electric Railway Association and the American Bureau of Welding has been completed. The failure of street railway rail joints in service is a source of great expense from the standpoint of maintenance, reduces the speed and effectiveness of the service, and greatly increases the noise of operation. Work on the development of a welded joint which will have a longer life is in progress.

*Welded structural members.*—In cooperation with the American Bridge Co. and the American Bureau of Welding a compression test was conducted on a steel column in which welded joints replaced the customary riveting. The results showed the column to be even stronger than expected, and this method of construction seems likely to come into more extensive use, particularly where noise is objectionable.

*Interlocking rib tile walls.*—There is much interest at present in buildings which will show greater resistance to earthquakes and hurricanes, and for this purpose walls with greater transverse strength are necessary. The strength of walls constructed of tile

with vertical ribs which interlock in the center of the wall has been investigated. The horizontal joints between the tile on the outside surface of the wall were also staggered with respect to corresponding joints on the inside surface. Tests of these walls showed a greater transverse strength than is obtained in tile walls of the usual construction. The compressive strength of the two types is about the same.

*Copper roofing.*—In cooperation with the Copper and Brass Research Association the conditions affecting the life of copper when used for roofing and for valleys and flashings have been investigated. The properties of sheet copper and of different methods of joining the sheets were also studied. Results have already been obtained indicating that the construction of copper roofs can be greatly improved.

#### INVESTIGATION OF FIRE-RESISTING PROPERTIES (\$28,100)

*Fire-loss statistics and fire prevention.*—Data for a paper on the seasonal variation in the fire loss obtained from State and press reports have been tabulated and charted.

Experimental methods have been developed for gauging the fire hazard of discarded matches, cigars, and cigarettes, and a number of tests were made to ascertain the relative hazard of several kinds of interior floors and wall coverings. Cigarettes are more likely to cause fires than cigars, because, in general, they burn longer after being thrown away.

*Insulated safes.*—Five fire tests of insulated record containers were made for Government departments and two for manufacturers.

*Fire intensity and duration.*—The larger structure, 30 by 60 feet in floor area, was burned out once with record-room occupancy and once with desks and filing cabinets. Four tests with metal furniture were made in the smaller structure, which, supplemented by a test with records on metal shelving due to be made in July of the present year, will complete the tests with office occupancy.

The severity of the fires with wood furniture was equivalent to approximately the first hour of the standard furnace test when wood flooring, furniture, and contents weighed 10 pounds per square foot, 1½ hours with 15, 2 hours with 20, and between 5 and 8 hours with the record rooms having 50 to 60 pounds per square foot of shelving and records.

*Strength of materials at high temperatures.*—The work on compressive strength of steel and cast iron was completed, 65 tests at temperatures of 750° C. being made on rounds and rolled shapes having slenderness ratios (l/r) from 22 to 144.

*Fire tests of roofing materials.*—Brand, flame, and spread tests were made on 126 decks of painted or chemically treated wood shingles, both new and weathered. Approximately the same number of tests were made on decks of weathered wood shingles and asphalt prepared roll roofing and shingles removed from building roofs 12 to 30 years old. Tests were also made of copper shingles, zinc standing seam roofing and shingles, copper-clad asphalt shingles, and asphalt saturated and coated asbestos felt roll roofings.

*Fire resistance of heavy walls.*—The fire tests of hollow tile walls were completed, 45 tests made during the year being of plastered, brick-faced, or furred walls, 12 or 16 inches in thickness, and of 8-inch walls made of tile for which the clay had been especially prepared by varying amounts of grinding, pugging, and admixture of combustible filler.

A supplementary series, consisting of fire-endurance tests of four brick walls and four hollow-tile walls that had been seasoned by accelerated methods to constant weight before testing, was added to obtain information on what effect the free water present in masonry walls for a considerable period after building has on the temperature transmission through the wall.

#### INVESTIGATION OF PUBLIC-UTILITY STANDARDS (\$100,000)

*Measurement of high voltages and large currents.*—Work has continued on the absolute electrometer designed to give a fundamental basis for measurements of voltages up to at least 250,000 volts. The year has been devoted largely to perfection of the actual measuring and weighing devices—gauge rods, balances, weights, and controls. In order to correlate electrometer measurements of effective voltage with crest or maximum voltages as measured by the sphere-gap or the corona voltmeter, an electrostatic curve-tracing apparatus has been developed. A study of humidity effects in the corona voltmeter has been made, showing that humidity has an appreciable effect under some conditions. A tubular noninductive oil-cooled shunt for 1,000 amperes has been completed, and studies of its performance have been made as a basis for the design of similar shunts for larger currents.

*Electrolysis and soil corrosion.*—Papers on methods of electrolysis testing and on applications of the earth current meter are in press. One on methods of electrolysis mitigation has been prepared and submitted to the American Committee on Electrolysis for discussion. Since many different interests are affected and there are wide differences of opinion regarding the choice of methods for preventing damage by stray currents, publication of this paper is likely to be delayed. Some 2,000 specimens of metals and protective coatings buried in various soils have been examined during the year. These constitute the second lot of specimens in this investigation which is planned to run for a total period of 10 years, and the preliminary nature of the present results is emphasized. Nevertheless, there is very widespread interest, and reports have been presented at four meetings of technical organizations.

*National Electrical Safety Code.*—All five parts of the new (fourth) edition of the National Electrical Safety Code have now been published as handbooks of the bureau.

*Government telephone surveys and patent suits.*—The numerous changes which have been made in location of bureaus in Washington, as well as changes in character and amount of business handled, have made necessary the continuation of telephone service studies under the auspices of the chief coordinator's office. Detailed studies are also being made to determine the best and most economical arrangement of telephone service for the group of new buildings recently authorized by Congress. These surveys, with a few others



outside the District of Columbia, the arrangement of general telephone service contracts, and the assistance given the Departments of Justice and War in defending suits for infringement of patents have occupied the full time of the bureau's telephone section.

*Gas water heaters.*—An investigation of the behavior of water heaters was carried out in cooperation with the testing laboratory of the American Gas Association in order to establish specifications for these appliances. The various factors relative to burner design and service conditions at the burner when using different fuel gases are being investigated. A theoretical study of the characteristics of flames for the purpose of adapting the results to the investigation of gas burners and appliances has been in progress.

*Production of water gas.*—A review of the entire literature relating to the economic factors involved in the production of water gas from both coke and coal has been made and should be of considerable value to public utility commissions.

*Gas analysis apparatus.*—A thermal conductivity apparatus was constructed for the Bureau of Mines for use in gas analysis in the investigation of mine explosions.

#### TESTING MISCELLANEOUS MATERIALS (\$44,090)

*Variety of materials tested.*—A great variety of chemical and physical tests were made for Government departments on paints, varnishes, roofing, and waterproofing materials; rubber; writing materials; boiler waters and compounds; technical chemicals; and detergents. A large number of miscellaneous materials were tested to determine their fire hazard in order to furnish data to guide the Steamboat Inspection Service in making rulings on the transportation of commodities on passenger vessels.

#### RADIO RESEARCH (\$49,800)

*Radio-frequency measurements and standards.*—The radio work was largely concentrated on two main problems—the improvement of frequency measurements and the development of radio aids to air navigation. The latter work was largely supported by funds transferred from the Aeronautics Branch of the Department of Commerce and will be described under "Transferred funds." The development of broadcasting and increased uses of radio generally rendered imperative greater accuracy in the measurement of frequency or wave length. Experiments to improve radio-frequency standards were conducted, apparatus was tested, and standards were disseminated in such a way as to make them of most value in maintaining broadcasting and other stations on the correct frequencies. The piezo-oscillator received much attention. With the cooperation of other Government departments and large electrical companies a program of research was begun looking to the development of this apparatus and its standardization to the highest possible accuracy, the aim being to secure a very considerable improvement over the present attainable accuracy of about 0.01 per cent. Comparisons with all important radio laboratories abroad showed that most of them were in agreement to the order of 0.01 per cent, but it is highly desirable

to establish absolute frequency values with a certainty of 0.001 per cent, and to do so will require much more research and development.

*Radio wave phenomena.*—The work on radio wave phenomena has included studies of fading and its correlation with other natural phenomena, such as terrestrial magnetism and electrical conditions on the sun. A definite connection appears to exist between solar phenomena, such as the rotation of the sun and the sun-spot cycle and radio conditions on the earth. Methods of measuring radio field intensity have been developed, as well as means for calibrating apparatus for these measurements. This work is increasingly important in view of the close control exercised by the Federal Radio Commission over the power and interference production of broadcasting stations.

#### COLOR STANDARDIZATION (\$9,000)

*Color standards in industry.*—Color plays a much more important part in industry and commerce than is generally realized. Requests are received in large numbers for advice on the standardization of colors for railway signals, highway signals and signs, building materials, paints, dyes, food products, and many other commodities. In no field probably is it more difficult to set up a satisfactory standard because the science of colorimetry lies in that borderland between physics and psychology where so much depends on the human observer. Nevertheless, progress is being made. A standard for artificial sunlight has been established for colorimetric purposes, many light sources have been graded, and numerous phases of the psychophysical aspects of the problem have been studied.

*Visual color responses and their physical stimuli.*—While colorimetry is preeminently a psychophysical subject, the basis of color specification lies in physical measurements of emission characteristics of light sources, transmissive characteristics of transparent materials, and reflective characteristics of more or less opaque materials. In cooperation with the Munsell Research Laboratory, progress has been made in the study of colorimetric sensibility, the elementary color excitation functions, and the analysis of color in terms of dominant wave length and purity, all of which serve for the colorimetric interpretation of these physical characteristics.

*Standard Lovibond color scale.*—For several years a research program has been under way with the object of finding an adequate basis for measuring and specifying color in trade. An important part of this program has been completed in the establishment of standards for Lovibond red and yellow glasses used in the vegetable oil and other industries. Having such standards, the next step is the calibration of perhaps several hundreds of these glasses for the trade, very slight differences in which often lead to disputes involving thousands of dollars.

*Apparatus for measuring the reflective characteristics of materials.*—For specifying the color of opaque diffusely reflecting materials a means of measuring reflectance under various conditions of illumination and as a function of both wave length and angle of view is necessary. A satisfactory experimental solution requires very complicated apparatus. During the past year this was designed, constructed, and placed in successful operation.

## INVESTIGATION OF CLAY PRODUCTS (\$47,000)

*Use of feldspar in whiteware.*—This investigation has been continued by further tests of grain fineness, mineral constituents, thermal dilatation, relative translucency of vitreous bodies in which the feldspar is the only variable component, and resistance of glazed ware to thermal shock. Specimens for the thermal shock test represented various combinations of feldspars in the glaze with the same and other feldspars in the bodies on which the glazes were applied. The data indicate that (1) screen analyses by various laboratories may differ sufficiently to make specifications to closer than  $\pm 0.5$  per cent of little significance, (2) differences in chemical analyses are sufficient to justify further investigation to determine the cause and control of present variations, (3) refractoriness of feldspar increases and the softening range decreases with increase in  $K_2O$ , (4) softening points range from that of cone 4 for soda feldspar to that of cones 9 to 10 for potash feldspar, (5) translucency for vitreous bodies containing potash feldspars increases with increase in the  $K_2O$  content of the feldspar, (6) mechanical strength is affected more by the method of firing than by the feldspar, (7) thermal expansion of vitreous bodies is increased by rapid firing and by increasing the  $Na_2O$  content of the feldspar.

The work on whiteware also includes a comparison of English and American china clays. All of the usual standard tests for both unfired and fired clays are to be covered, and a study of 17 English clays is now in progress.

*Drying of clay bodies.*—Preliminary drying studies of 12 typical clays have been completed, a method of routine testing developed, and a report correlating the drying results with previous investigations of the same clays with respect to water smoking and oxidation is in course of preparation. At the Columbus branch 19 clays have been selected for the purpose of studying the qualities characterizing clays used in the manufacture of heavy clay products.

*Workability of clays.*—The power efficiency of extrusion machines as affected by various combinations of dies, spacers, and type of auger has been studied, using a clay which did not change in workability after repeated extrusions. The data indicate that the single wing auger (6-inch),  $1^\circ$  taper die and 6-inch spacer is the most efficient combination for the clay used.

*Vitreous enamel ground coats.*—The effects of different proportions of flint and feldspar and various combinations of fluxes have been studied. In general, flint in the refractory portion and sodium oxide in the flux portion were most resistant. Boric oxide increased resistance to mechanical shock in the series of ground coats containing flint and feldspar in approximately equal proportions. Variations in expansivity influenced resistance to mechanical and thermal shock less than is the case in cover coats. A light-colored ground coat of sufficient adhesiveness is hard to obtain without the use of cobalt, which produces a dark color. A new test for measuring adhesiveness has been devised. Opacifying materials have also been studied to determine which can be used in the mill batch of a ground coat without danger of reaction with the metal base and evolution of gas. Zirconium oxide and sodium antimonate have appeared satisfactory.

Methods of treating the metal to increase the adhesiveness of the enamel have been tried with promising results.

*Consistency of enamel suspensions.*—This investigation has been completed. A new component of consistency which is called "set" (of which the draining period is a measure) has been discovered, and a new method worked out for computing and expressing "relative mobility." Correlation of data obtained in two factories led to the conclusions that (1) the weight of enamel slip retained on a unit area of the iron base is a function primarily of yield value and secondarily of "set," (2) mobility can be completely controlled in practice by varying the water content of the slip, and (3) the measure of "set" known as draining period is roughly a hyperbolic function of mobility.

*Study of glazes.*—The properties of tensile strength and elasticity of about 85 glazes have been determined and data correlated to develop laws regarding the effect of various components of the glazes on these properties.

As a corollary to this work, some study has been made on the type of strain present in a glaze fired to a body. The evidence so far shows glazes which have crazed to be in tension and those of good fit to be in compression, as a general rule.

#### STANDARDIZING MECHANICAL APPLIANCES (\$27,800)

*Elevator safety interlocks.*—Work on elevator interlocking devices has been extended to include numerous reliability tests of commercial interlocks requested by regulating bodies. The results are used as the basis for approval by several of the Government departments, by the District of Columbia, by various municipal and State governments, and by a group of casualty insurance companies.

*Elevator research.*—An investigation of the performance of elevator safety equipment, particularly oil buffers, undercar safeties, governors, and their associated mechanisms, is being conducted under a fellowship established by the American Engineering Standards Committee. The ultimate purpose of the work is the preparation of specifications for performance tests of elevator safety equipment.

An elevator machine has been installed, and special instruments are being developed to measure the deceleration, which takes place in a relatively short time and may attain a value three times that of gravity.

*Altitude chamber for testing instruments.*—This is a steel tank, large enough to accommodate two observers, in which the pressure can be lowered to correspond to an altitude of 30,000 feet. It has been useful in adjusting and testing instruments for aircraft and in calibrating mercurial barometers by comparison with a standard instrument. Temperature control within the chamber is now being installed.

*Testing of engineering instruments and mechanical appliances.*—There has been an increase of approximately 20 per cent in the testing of engineering instruments and mechanical appliances, including the calibration of stream flow meters, the testing and investigation of new fire extinguishing devices, and the testing of devices and equipment purchased by the Government departments under performance specifications.

*Radiator air valves.*—The investigation of radiator air valves has been continued at the request of the Supervising Architect's Office. Definite performance specifications have been in use during the past six months.

#### INVESTIGATION OF OPTICAL GLASS (\$20,520)

*Production of optical glass.*—In studying the factors affecting the quality of optical glass during melting, molding, and annealing, a total of approximately 21,000 pounds of glass of four different kinds were made in 18 pots, one of which contained about 4,000 pounds. Most of the perfect glass obtained was molded into prisms and lens blanks of various sizes from which the naval optical shop received 21,441 blanks.

*Viscosity.*—The friction of the rotating parts of the viscosity machine has been reduced to such an extent that the friction correction for any load is now definitely known, and errors in viscosity determinations caused by uncertain or variable friction correction are entirely eliminated. This will increase the accuracy of measurements and permit a more thorough study of other variable conditions affecting viscosity determinations.

*Annealing or the reduction of strain in glass.*—Recently it has been shown that the temperature at which glass is annealed has a decided effect on the index of refraction (and also density) of the glass. Glass from the same melt may have different indices of refraction if annealed at different times. These differences are great enough to explain differences in focal lengths of similar optical systems and variations from computed focal lengths which previously were thought to be caused by lack of homogeneity in the original glass or faulty surfaces. Critical studies on this phase of the work are being continued.

*Large glass disk.*—A large glass disk for a reflecting telescope was satisfactorily cast by pouring the molten glass into a mold, which is at the same time an electrically heated annealing furnace. The disk, made of borosilicate crown glass, is approximately 70 inches in diameter, 12.5 inches thick, and weighs about 4,000 pounds. The cast-iron furnace (or mold) weighs 5 tons and the insulation (sil-o-cel) about 2 tons. The glass is allowed to cool about 2° C. per day, and the annealing will require a constant temperature for about six weeks, after which slow cooling will again be started. The initial cooling, annealing, and final cooling of this disk will take about 10 months, and since it was cast in May it will not be cold until about February.

#### INVESTIGATION OF TEXTILES, ETC. (\$35,000)

*Physical characteristics of mohair fiber.*—Data regarding the physical characteristics of mohair fiber were obtained to supplement the technical and economic information on the mohair industry now being collated by the Departments of Commerce and Agriculture. Strength and diameter measurements were made. A photomicroscopic study of the mohair fiber and mohair kemp was prepared. Cross sections were prepared thin enough to show the cellular structure of the kemp as compared with the almost solid structure of the mohair fiber.

*A resilience test for fabrics.*—A method of measuring the resilience of a textile fabric has been developed in connection with a determination of the characteristic properties of silk as contrasted with mercerized and doped cotton fabrics. The apparatus employs a balance acting as a loading device and a movable platform on which a test specimen is placed. Measurements are made by placing a fold of the fabric on the platform, then applying compression by means of the balance, then noting the amount of compression of the fold of the fabric under gradual loading and its return when the load is removed.

*A stress-strain test for rayon yarns.*—An investigation of the effect of moisture on the properties of rayon required a more accurate test method than was available. The method developed differs from the lea test on which it is based, in the control of the tension of the individual strands which make up the test specimen.

The apparatus consists of a U-shaped rod on which the yarn is wound by means of a yarn winder (ordinarily used for evenness inspection), a tension device consisting of three highly polished metal disks, and a transfer clamp for taking the specimen from the U rod to the jaws of the testing machine.

The results obtained on rayon yarns using this "equitension lea method" have shown that further elaboration of technique of multiple yarn test methods would not be warranted unless more sensitive strength machines are used; that is, the variations are within the limits of the machine.

*Standardization of paper-testing methods.*—In cooperation with the Technical Association of the Pulp and Paper Industry numerous official paper-testing methods were developed. A member of the bureau's staff acted as chairman of the association's paper-testing committee which conducts the development work. Twenty-one methods have been completed and officially adopted by the association.

*Paper fibrous raw materials.*—Successful results were obtained in paper-making tests of various fibrous raw materials. It was found by semicommercial experiments that paper equal to that made from high-grade rags could be produced from the Caroá plant, native of Brazil. Tests of waste mail pouches made for the General Supply Committee demonstrated their excellent paper-making value and resulted in disposal of them to paper makers at an increased annual profit of \$17,000. A good grade of wrapping paper was produced from waste fibrous material, which is a by-product of the manufacture of manila rope, at the Boston Navy Yard. This opens up the possibility of profitable disposal of it to paper makers.

*Paper currency.*—Treasury Department statistics show that the cooperative research with the Bureau of Efficiency and the Bureau of Engraving and Printing on improving the quality of United States paper currency has increased its average life to 10 months as compared with the former figure of 7 months. The importance of this work is evident when it is remembered that the cost of producing a year's supply of paper currency is around \$10,000,000. One of the chief contributing factors to the greater wearing quality of the present paper currency is the development in the experimental paper mill of a distinctly new type of paper characterized by great fiber strength.

## SUGAR STANDARDIZATION (\$38,160)

*Production of hard refined levulose.*—The production of levulose has resulted in great interest throughout the country in the possibility of a new American industry. Approximately 100 pounds of this sugar was manufactured and distributed to various parties for experimental purposes. A part was used with diabetics, of whom there are about 2,000,000 in the country. Having satisfactorily demonstrated that it is a physical possibility to produce granulated levulose in quantity, a semifactory scale experimental plant has been designed and is now being installed. This is intended to supply the engineering information necessary for designing a commercial factory.

*Production of dextrose.*—The utilization of corn by the dextrose industry, an outcome of the bureau's activities, has apparently gone far to solve the surplus corn problem. During 1926 the production of crystalline dextrose amounted to over 200,000,000 pounds, and the demand now exceeds the capacity of the producing plants. Production has doubled each year for the past three years.

*Carbohydrate investigations.*—One new sugar compound, the existence of which was predicted by theory, has been made in the laboratory, and improved methods for preparing various sugar compounds have also been developed. Published researches bearing on the relations between rotatory power and structure in the sugar group as carried on at the bureau are extensive and scattered over a number of years in various scientific magazines. A 142-page report has been published in which the essential discoveries have been collected and correlated. The need for this has been amply proven by the requests for the publication. It covers a number of important new sugar compounds which have been prepared and gives data relating to the structure of the compound sugars which have been obtained by the preparation of compounds of six sugars—lactose, cellobiose, maltose, glucose, mannose, and xylose.

*Import sugar and molasses.*—The sucrose in imported raw sugars and molasses is the largest single producer of revenue from the tariff. The supervision of the testing of these materials in the customs laboratories was carried on with such success that the Government was involved in practically no expense for litigation during the current year. The increase in the importation of molasses necessitated further studies with the object of increasing the precision with which the duty could be determined. The methods developed have been adopted throughout practically the entire molasses industry.

*Duty on Cuban granulated sugar.*—The Treasury Department was confronted with a new problem in collecting revenue on granulated sugar grown and refined in Cuba. The problem was solved at the bureau's suggestion by stationing a Federal inspector at the plant to supervise the testing and packaging of the sugar. His expenses are paid by the manufacturer, and duty on 100 per cent sugar is paid on each shipment. This avoids the necessity for any inspection when the sugar reaches the United States. The Government is, therefore, receiving a large increase in revenue at no additional expense.

## GAUGE STANDARDIZATION (\$38,320)

*Gauges for oil industry.*—About 65 per cent of the limit gauges tested have been for use in the petroleum oil industry. Marked progress has been made in the standardization of oil-well casing, drill pipe, cable drilling tool joints, and pumping equipment.

*Improvement of gauges and gauge steels.*—The design of threads and the heat treatment and accelerated aging of gauge steels to secure dimensional stability have been studied.

It has been found in practice that the percentage of full thread depth in nuts specified by the National Screw Thread Commission is in some cases unnecessarily high, and that it results in excessive power requirements for tapping and in excessive tap breakage, especially in the smaller sizes. Experiments to determine the maximum size hole that can be permitted in a nut and still develop the full strength of the mating screw show that the minimum depth of engagement may safely be reduced somewhat below the 75 per cent specified by the commission, probably as low as 65, and possibly to 60 per cent, or even less on the smaller sizes.

A ball-race steel and a straight carbon steel have been given accelerated aging tests. The steels are immersed in boiling water for 24 hours and then for successive periods of 100 hours each, the change in length of each specimen being determined after each period of boiling. One group of specimens of ball-race steel was practically stable after 24 hours boiling. Another group was stabilized after 124 hours boiling. These specimens have been measured at frequent and regular intervals during the past eight months, and no change greater than 0.00001 inch in a 4-inch specimen has been found. Other specimens of ball-race steel and all of the straight carbon steel specimens were given a different heat treatment and were not stabilized after 1,400 hours of boiling.

*Improved equipment and testing methods.*—An improved method of measuring the thread angle of ring gauges has been developed, and plaster of Paris has replaced sulphur and graphite as the most suitable material for making casts of threads in ring gauges.

Two projection lanterns of an improved design have been constructed—one for the Ordnance Department of the Army and one for the Naval Gun Factory, Washington, D. C.

*Cooperation.*—Under this fund cooperative work has been carried on with the National Screw Thread Commission, the Federal Specifications Board, the Gauge Design Committee, and the American Petroleum Institute in the field of design and test of screw threads and limit gauges.

## INVESTIGATION OF MINE SCALES AND CARS (\$12,800)

*Tests of tippie scales.*—The mine-scale testing unit operated in the States of West Virginia and Ohio, making tests of 186 tippie scales at coal mines. Of these 79, or 42.5 per cent, were found correct within the prescribed tolerance. Incidental tests of 9 motor truck and wagon scales were also made by this unit.

This figure for accuracy is somewhat lower than last year, but it is subject to considerable fluctuation from year to year because of



the fact that the figure for a single year is not, and can not be, representative of the coal-producing regions as a whole. The scale-testing equipment works in different regions each year to meet special demands, and it takes two or three years to cover the whole territory. General experience over a period of years shows a gradual improvement in this type of scale.

#### METALLURGICAL RESEARCH (\$43,140)

*High-speed tool steel and the machinability of steel.*—The study of the effect of impurities and of added elements on the performance of high-speed tool steel has proceeded as usual. A report was issued on machinability of alloy steels under roughing cuts, and experimental study of finishing cuts was begun, following the suggestions of the metallurgical advisory committee.

*Steel for carburizing.*—In cooperation with the Bureau of Mines, the study of "abnormality" in steel for carburizing is nearly completed, and a progress report has been published. A final report is in preparation. This peculiarity in some steels has been shown to exist, although heretofore it has been doubted by some metallurgists.

*Corrosion of metals.*—Besides cooperation with the Navy, Army, and National Advisory Committee for Aeronautics on the corrosion of duralumin, cooperative work with the American Society for Testing Materials on accelerated corrosion testing of zinc-coated materials has been carried on. Work on electrolytic methods for corrosion testing has been completed and a report published. All corrosion appears to be electrolytic in nature. A report on comparative tests of nonferrous materials is nearly ready for the press. Work on the effect of aeration in corrosion testing is under way. Cooperative work with the American Society for Testing Materials in laboratory and exposure tests of nonferrous screen wire cloth continues.

*Molding sands.*—Cooperation with the joint molding sand committee of the American Foundrymen's Association and with the Washington Navy Yard has continued. Methods for avoiding the burning-on of sand have been studied and a letter circular issued. Progress has been made in the development of apparatus and methods for determining the sintering point of sand and of rapid methods for moisture determination.

*Substitutes for platinum.*—The working of pure rhodium as a substitute for platinum, though difficult, seems on the way to solution. Successful accomplishment of this would mean a saving to the bureau on account of the amount of platinum now required in scientific apparatus.

*Alloy steel.*—A special iron-carbon-vanadium alloy of great hardness was prepared, and its applicability to balls for Brinell hardness testing was studied and a report published.

*Bearings.*—In cooperation with a research associate from a manufacturer, bearing metals such as are used on railroads have been studied as to wear resistance and impact strength at ordinary and at service temperatures.

*Rails.*—In cooperation with a research associate from an engineering firm, a study has been made of the properties of rails made from ingots cast with hot tops. In cooperation with the American

Railway Engineering Association, the Manufacturer's Rail Steel Committee, and the American Society of Civil Engineers' Committee on Stresses in Track, work has been done on the endurance limit of rail steel under repeated stress. Work is under way on axial loading endurance testing to study some factors that are essential in further work on the endurance limit of rail steel. The properties of rail steel at high temperatures are also being studied. These problems are attacked because of their bearing on the question of rail breakage, especially through transverse fissures.

#### HIGH-TEMPERATURE INVESTIGATIONS (\$9,740)

*Pyrometry of molten brass.*—A study was made of the methods used in some 20 of the leading brass foundries to measure and control their pouring temperatures. The methods were analyzed and discussed in a paper presented before the American Foundrymen's Association and published as a part of their symposium on pyrometry. There appears to be a lack of knowledge of pyrometry in some foundries. Since most of the pyrometers on the market are satisfactory for measuring brass-furnace temperatures, there should be no difficulty in securing proper equipment, and undoubtedly the careful control of pouring temperature would result in a better product.

*Thermoelectric properties of metals.*—The thermoelectric properties of aluminum and thorium of high purity were determined as part of a program which is to include a study of all the metals which can be obtained in pure form. It is important to have on hand data of this kind to supply needed information when these metals are used industrially.

*Heat losses from a hot-metal car.*—The heat losses from a 75-ton hot-metal car were determined by the bureau at a plant of one of the large steel corporations. It was found that they were much less than from an open ladle. Steel could still be poured after remaining in the car for 40 hours. A paper on the subject was presented at a convention of the American Foundrymen's Association.

*Pyrometry of ferrous materials.*—A study has been made of the methods of observing the temperature in ladles and streams of molten cast iron. Observations made with a portable disappearing type optical pyrometer were compared with the true temperatures as found by the use of rare-metal thermocouples immersed in the metal and protected by graphite tubes. Work was carried out on a considerable variety of cast irons.

*Melting point of palladium.*—Using a value for  $c_2$  of 1.4325 cm.deg. and taking the melting point of gold as 1,063° C., the melting point of palladium was found to be 1,553.5° C.

If the new value of  $c_2$  (1.433 cm.deg.) is adopted for the international temperature scale, this value for the melting point will be lowered about 0.2°.

*Melting point of platinum.*—Work is in progress on the melting point of platinum, but the bureau is not yet prepared to announce the result.

#### SOUND INVESTIGATION (\$10,580)

*Acoustic properties of building materials.*—Sound transmission measurements were made on 24 panels, mostly of masonry construction, and including 4 floor panels. A dead air space was found to be

the best sound insulator. No filling material can approach air in this respect. Measurements of sound absorption were also made on 20 substances commonly occurring in construction. These values of sound absorption are of importance in predetermining the acoustic qualities of a proposed auditorium. An accoustical plaster is also being developed which it is believed will remedy acoustical defects in about 90 per cent of the auditoriums, churches, etc., now having objectionable echoes.

*Rating of tuning forks.*—Requests are often received to measure the frequency of vibration of tuning forks submitted by makers of musical instruments. The bureau keeps no standard forks but compares every fork submitted with a primary standard of time in the shape of a freely swinging pendulum in a vacuum. The comparison of two vibrations as different in frequency as a tuning fork with a period of perhaps a thousandth of a second and a half-second pendulum presents considerable difficulty. During the past year a photographic method for accomplishing this has been developed by which the desired comparison can be made to 1 part in 25,000 in a period of 2 or 3 seconds.

#### INDUSTRIAL RESEARCH (\$174,120)

*Properties of rubber-sulphur compounds.*—Samples ranging from 2 to 32 per cent of sulphur have been made, the density, dielectric constant, power factor, and resistivity measured, and the results give evidence of definite chemical compounds not previously known to be formed and dispel the mystery heretofore associated with vulcanization.

*Storage-battery investigations.*—A small-scale manufacturing plant has been assembled to make battery plates for experimental purposes in order to find out the effects of various materials and different methods of preparing grids and pastes. Several special investigations have been made to determine the conditions under which batteries should be shipped or stored in order to avoid deterioration. Effects of temperature during discharge have been studied with reference, first, to the design of batteries for use at low temperatures, as in airplanes, and, second, to the specification of conditions under which ratings of batteries should be determined. Other conditions affecting rating and performance of batteries have also been studied, and the results have been used in preliminary work on battery specifications for the Federal Specifications Board and in an American Institute of Electrical Engineers' report on standards for storage batteries.

*Gases in metals.*—Progress was made in the study of vacuum-fusion methods for gases in metals, especially for nitrogen, and representatives of manufacturers have studied the apparatus with a view to using it in commercial laboratories. Specimens of iron, the oxygen, hydrogen, and nitrogen content of which had been determined have been sent to scientists in England, Sweden, and Germany, who are also working on methods for analyses and intercomparison of the methods in use.

*Metal spray.*—The study of sprayed metallic coatings has been continued and the military aspects investigated in cooperation with the

Army and Navy. A coating of pure aluminum was found very effective in preventing intercrystalline embrittlement of duralumin.

*Heat-resisting alloys.*—Attention has been paid to the relation between behavior of heat-resisting alloys in long-continued loading tests at high temperatures and short-time tests made with especially sensitive equipment in order to secure more quickly and cheaply the data required by the engineer in designing high-pressure power plant equipment, oil-cracking stills, nitrogen-fixation apparatus, etc.

*Quenching media.*—Study of quenching in and quenching media for the heat-treatment of steel has continued. Methods for treatment of low carbon steel developed by industry with the aid of information contained in bureau publications on this project, are finding rapidly increasing commercial application.

*Journal bearings.*—The design of journal bearings is still almost wholly a matter of trial and error. As a part of a program, which is expected to put this entire subject on a rational basis, probably in chart of tabular form an investigation of the effect of running in before newly manufactured bearings are put in service has shown that subsequent friction losses can be considerably reduced and the load-carrying capacity increased.

*Thermal expansion.*—A research on the expansion of beryllium and its alloys has been completed; 11 tests have been made on nickel steels of compositions near but not at the invar composition, and 12 tests of stainless iron and other iron alloys have been made. This work is done in continuation of a policy adopted several years ago of working up complete data on groups of related alloys as early as possible after their appearance in commercial use.

*New expansion apparatus.*—A new and simple type of thermal expansion apparatus has been constructed and thoroughly tried out and found to be highly satisfactory for obtaining results of moderate precision (better than 2 per cent). It has already been used by two commercial laboratories and found to be well suited to their needs.

*Dental materials.*—Attention has been directed to studies of the shrinkage of dental castings, length changes in inlay wax when manipulated as in dental practice, porosity of castings, making inlays to exact dimensions, and the elimination of finlike defects and rough surfaces on castings. The results obtained have been of value to the Veterans' Bureau and to the office of the Surgeon General in the preparation of tentative purchase specifications for dental materials.

*Optical design.*—Optical calipers (which are free from the errors of contact methods) for measuring the wall thickness of compressed-gas containers, and an internal-inspection device for these containers, a new magnifying stereoscope for the United States Geological Survey, and a large-aperture four-component telescope objective for special work have been designed.

*Investigations in atomic structure.*—Progress in the development of artificial illuminants and of many important devices involving electron emission is dependent upon knowledge of the nature of collisions between atoms and electrons. Any contribution to our knowledge of the mechanism of radiation and of the structure of atoms is certain to result in new applications of value from the utilitarian standpoint. Notable examples of such development are the Coolidge X-ray tube and the entire field of radio tube design. In its studies

in the field of atomic physics the bureau has investigated the energy changes following resonance excitation of mercury vapor as well as problems relating to molecule formation in hydrogen and metal vapors.

With the mercury vapor exposed to  $\lambda 2537$  radiation, the intensity of the radiation thereby excited is more or less reduced by the addition of foreign gases. The detailed processes by which the energy of excitation is passed on to the foreign molecules are consistently explained.

In cooperation with the National Research Council an investigation of hyperfine structure has been carried on, especially the study of that of the  $\lambda 2537$  line of mercury in the magnetic field. The magnetic anomaly observed in this line was traced to a single one of the five components.

*X-ray investigations.*—The ordinary plane diffraction grating ruled on glass, receiving the radiation at nearly grazing incidence, has been successfully applied for measuring the wave length of the  $K\alpha$  radiations of aluminum and carbon;  $L\alpha$  radiations of copper, iron, and chromium; and the  $M\alpha$  radiations of platinum. X-ray protective plasters consisting of various mixtures of materials containing the heavy atoms of lead and barium were investigated and the results published.

*Photographic emulsions.*—The performance of emulsions prepared with different bromides has been studied. Satisfactory explanation of these results by well-known chemical and physical principles fortifies the hope that eventually the whole subject will be reduced to a logical basis. One phase of the fundamental problem of photographic sensitivity has been dealt with by experiments on the sensitization by colloidal particles. These have definitely confirmed the possibility of sensitization by photochemically inert nuclei and indicated the mechanism by which this occurs.

*Determination of sulphur trioxide in sulphur dioxide.*—The refrigeration industry and the manufacturers of liquid sulphur dioxide have been unable to determine the amount of sulphur trioxide in sulphur dioxide, owing to the nonexistence of a satisfactory analytical method. An accurate method for this purpose has been worked out.

*Light fading and washing of fabrics.*—Investigation on light fading and washing tests has been made in cooperation with the research committee of the American Association of Textile Chemists and Colorists. A by-product of the work was a proposed classification of dyed fabrics according to their fastness of color. This was prepared to aid the Converters' Association and related organizations in their plan to label fabrics sold to retailers for the benefit of the ultimate consumer.

*Fractional distillation of gases.*—Studies of the separation of gas mixtures by fractional distillation at low temperatures and pressures have been productive of several new methods for the separation of natural gases with especial reference to the determination of natural gasoline fractions. A commercial apparatus was designed and has been used successfully in an industrial laboratory.

*Sole leather.*—Data on the comparative durability of chrome and vegetable tanned sole leathers, published some time ago, created

a demand for information as to the comparative durability of vegetable and chrome retanned sole leathers. Several series of tests have been in progress, using material supplied by five tanners. Retanned leathers used have varied from a light retannage with vegetable materials just sufficient to color the leather throughout its thickness to a heavy retannage which caused the leather to resemble vegetable leather in appearance. The results indicate that the light retanned leathers will wear about 75 per cent longer than vegetable and that the heavy retanned leathers will wear about 25 per cent longer than vegetable leather.

*Acid in leather.*—Work has been started to determine the effects of sulphuric acid on the life and properties of vegetable-tanned leather. Tanning of hides was carried out so as to produce standard leather samples tanned with ordinary quebracho, chestnut wood, and sulphited quebracho extracts. The last represents both the catechol and pyragallol types of tanning materials used by the industry. Samples of each of the standard leathers were treated with sulphuric acid varying in amount from 0 to 4 per cent. Each sample was then tested for original strength and stretch, and the remaining portion was placed in storage for the particular aging period involved. The aging periods to be used are 2, 4, 6, 9, 12, and 24 months. No results of aging tests are yet available. Considerable information was secured relative to the acid content of the leather by the use of the modified Proctor & Searle, total sulphur, and potentiometer methods. This research has been actively supported by the industry through an advisory committee.

*Guayule rubber.*—An investigation of guayule rubber, in cooperation with the Continental Rubber Co., has shown that by proper treatment during its preparation for market this rubber compares favorably with plantation Hevea rubber, the latter now comprising about 95 per cent of the world's supply. The commercial production of good quality guayule rubber will not only tend to stabilize the crude rubber market, but will also provide a cheaper native product which can be used as a substitute for the more expensive imported Hevea rubber.

*Aging of soft rubber.*—The first phase of the work on the aging of soft rubber compounds under different conditions of storage and exposure has been completed. The results show that heat, light, and oxygen contribute independently to the deterioration of rubber compounds, but that their effect is not the same on all compounds.

*Antifreezing solutions for automobiles.*—Further studies of glycerine-water radiator solutions, suggested by criticisms of their performance in service, have been undertaken as a preliminary to recommending Federal specifications for radiator solutions. A number of commercial antifreeze preparations have been examined, but no new materials of such merits as to warrant mention have been found.

*Lubrication of aircraft engines under starting conditions.*—Measurements of the rate of flow of some 35 commercial lubricating oils through the oil passages of a Wright J-4 engine, mounted in a cold chamber and slowly motored over, have been completed. The conclusion, earlier indicated, that neither the pour point of an oil nor its viscosity at 99° C. (210° F.) is sufficient to determine its performance

in the engine at temperatures below  $0^{\circ}$  C. has been confirmed. It is of interest to note that an oil reported to have been used on the Byrd polar flight in an engine of this type failed to flow to the pump at both test temperatures ( $-6^{\circ}$  C. and  $-3^{\circ}$  C.).

*Properties of steam.*—The equipment has been set up in the new quarters. The calorimeter was assembled, tested, auxiliary equipment consisting of thermocouples, resistance thermometers, thermostatically controlled baths, vacuum pumps, apparatus for electric measurements, and apparatus for purifying water, and for controlling and measuring the water was installed and the whole put into operation. Preliminary observations of the heat content of water up to  $130^{\circ}$  were made, and the technique of operation and measurement was developed. This work, which is in cooperation with the American Society of Mechanical Engineers, will yield data now badly needed on the properties of saturated steam at pressures up to 1,240 pounds per square inch, corresponding to a temperature of  $300^{\circ}$  C.

*Heat transfer through air spaces and from surfaces in free air.*—A critical review and correlation of the available data on these allied subjects was largely completed. This work is in cooperation with the heat transfer committee of the National Research Council in the effort to obtain practical working data of reasonable accuracy from the mass of rather discordant results to be found in the literature.

*Heat transfer through building construction.*—A large number of tests have been made on hollow frame wall construction under various conditions with various types of radiation shields within the air space. Tests were also made on panels of solid and of hollow brick construction. The results of these tests will permit calculation of the heat transfer through various types of walls without requiring a test on the completed wall.

*Wind pressure on structures.*—Because of large scale effects wind-tunnel measurements on models of tall chimneys can not be safely applied to full-scale structures. The bureau has decided to supplement wind-tunnel investigations by measurements on large cylinders in a natural wind. A cylindrical stack 10 feet in diameter and 30 feet high has been erected in an exposed position on the roof of one of the bureau's buildings. Measurements on the pressure distribution over this cylinder will be made during the coming year.

*Superheatmeter.*—This instrument, developed in cooperation with the Naval Bureau of Aeronautics, is used to measure directly the difference in temperature between the lifting gas in the cell of an airship and the outside air. The apparatus consists of a number of thermal elements in series, one set of junctions being in the gas cell and the other set exposed to air temperatures. A galvanometer, included directly in the circuit, is graduated to show directly the difference in temperature between the two sets of junctions.

*Sphygmomanometers.*—These instruments are used by physicians for the measurement of blood pressure. Two types are employed, in one of which an aneroid capsule is used and in the other some form of a mercury manometer. At the joint request of physicians and manufacturers an investigation of these instruments has been carried out in the course of which methods of testing were developed and tolerances established which appear to meet with general approval.

## TESTING RAILROAD-TRACK AND OTHER SCALES (\$39,000)

*Railroad-track scales.*—During the year tests were made of 840 railroad-track scales located in 35 States and the District of Columbia. The tests were conducted by three testing units operating over 73 railroad systems. Of the scales tested 465 were owned by railways, 364 by industries, 5 by States or municipalities, and 6 by departments of the Federal Government. Seventy-three scales were adjusted to correct excessive weighing errors.

An analysis of the test results shows that of all track scales tested 70.1 per cent were correct within the allowed tolerance. This represents an increase of approximately 5 per cent over the corresponding item for the preceding year and indicates a notable improvement in the accuracy of carload freight-weighing equipment. The average error for all scales tested was 0.21 per cent, a value which exceeds the tolerance limit by only 0.01 per cent.

Evidence of improved weighing conditions is most marked in the eastern district, where 75 per cent of the scales tested were within the tolerance, and the average error for all tested scales was only 0.16 per cent.

In the western district the beneficial effects of applying systematic maintenance measures to railroad-track scales are reflected in the figure of 77.8, representing the percentage of railroad-track scales found within tolerance.

Results for the southern district do not differ appreciably from those for last year, but advanced accuracy is expected to follow recent concentration of testing activity in that section.

*Master track scales.*—Fifteen master track scales were calibrated and found to be correct within the established tolerance. At the close of the year five master scales remain uncalibrated because of a shortage of operating funds. At this time cognizance should be taken of the fact that several master scales are now regularly called upon to standardize test cars weighing 100,000 pounds. The bureau is now without sufficient equipment to calibrate master scales to these capacities.

*Railroad-track scales in grain-weighing service.*—Of the 364 industry-owned track scales already discussed, 67 were used for weighing grain at mills and elevators. Of these, 26 scales, or 38.2 per cent, were found to be weighing within the special tolerance provided for this class of weighing service. Twenty-two scales found incorrect were adjusted to secure performances within the special tolerance. There is apparently no pronounced change in the general accuracy characteristic of grain scales during recent years. It is rather generally accepted that the current tolerances for this class of track scale are too stringent to be met by many scales used at mills and elevators.

*Specifications.*—Through representation on a subcommittee of the American Railway Engineering Association's yards and terminals committee the bureau during the past year cooperated actively in the preparation and promulgation of a code of specifications for two section track scales. These specifications have been formally approved and accepted by the American Railway Engineering Association and are shortly to be published by the bureau.



*Test-car calibrations.*—In connection with the field schedules of the track-scale testing units 32 track-scale test cars were calibrated for railroads and industries that were without master-scale facilities. Several new test cars of the type recommended by this bureau were placed in service the past year, of which approximately half were of 100,000 pounds standard weight. Casual survey of the calibration records finds the situation improved with respect to accuracy of test-car maintenance.

#### MASTER TRACK SCALE AND TEST CAR DEPOT (\$50,000)

*Donation of site for master track scale depot.*—A site in clearing yard of the Belt Railway Co., of Chicago, just outside the city limits of Chicago, for the location of the master track scale depot, was donated in fee simple to the Government by the Chicago & Western Indiana Railroad Co., through arrangement with the General Managers' Association of Chicago. This splendid cooperation is very much appreciated. Plans for the building were completed and contracts were awarded for its construction and equipment. Excavation has commenced, and during the coming year the station should be put in operation. This station will calibrate the bureau's track scale testing equipments as well as those owned by railroads and operated throughout a very large region about Chicago, heavy weights, etc. It should be of tremendous help to the railroads and industries as well as to the bureau.

#### STANDARDIZATION OF EQUIPMENT (\$115,000)

*Adherence to simplified practice recommendations.*—The outstanding development of the past year is the strengthening of support for and adherence to the simplified practice recommendations developed by various industries.

Recognizing that a relatively high degree of adherence makes any simplification program effective, cooperation has been extended to industries in perfecting a procedure, providing, among other things, for the appointment of a representative standing committee as a liaison service between the Department of Commerce and the industry concerned. This committee is charged with the duty of promoting, encouraging, and supporting the findings of the conferees, as well as conducting annual resurveys to ascertain the degree of adherence and to effect reaffirmations or any necessary revisions.

Annual audits or resurveys, conducted by the standing committees in 18 different fields, revealed that there is an average degree of adherence of 79.5 per cent. This indicates that the sizes, etc., adopted and published as simplified practice recommendations are being applied in the products themselves.

In many instances the data collected through the resurveys served not only to demonstrate the degree of adherence but also provided a basis for further eliminations or substitutions, thereby making it possible to keep the simplified practice recommendations up to date and in line with the best current practice of the industry concerned.

Individual commodities and the degree of adherence in percentage are detailed below.

(a) Degree of adherence obtained by actual survey

S. P. R. No.	Title of recommendation	Adherence	S. P. R. No.	Title of recommendation	Adherence
		<i>Per cent</i>			<i>Per cent</i>
1	Paving brick.....	79	20	Steel barrels and drums.....	84
2	Bedsteads, springs, and mattresses.....	51	24	Hospital beds.....	69
3	Metal lath.....	99	25	Hot water storage tanks.....	82
4	Asphalt.....	74	28	Sheet steel.....	53
7	Face and common brick.....	74	30	Terne plate.....	95
8	Range boilers.....	99	32	Concrete building units.....	98
9	Woven-wire fencing.....	97	36	Sand lime brick.....	62
12	Hollow building tile.....	84	46	Tissue paper.....	70
16	Lumber.....	80		Average.....	79.
19	Asbestos paper and millboard.....	82			

(b) Degree of adherence estimated by industrial leaders

S. P. R. No.	Title of recommendation	Adherence	S. P. R. No.	Title of recommendation	Adherence
		<i>Per cent</i>			<i>Per cent</i>
10	Milk bottles and bottle caps.....	75	31	Loaded paper shot shells.....	81
26	Steel reinforcing bars.....	85		Average.....	84.5
29	Eaves trough and conductor pipe.....	97			

*Simplified practice recommendations accepted.*—Up to the present time simplified practice recommendations have been accepted by manufacturers, distributors, and users of 62 commodities.

*Recommendations in process of acceptance.*—Simplified practice recommendations for 14 items have been proposed and approved at a general conference of manufacturers, distributors, and users and are now in process of acceptance by the various groups interested.

*Field surveys in progress.*—Surveys of existing varieties are in process for 37 industries.

*General.*—Seventeen general conferences of manufacturers, distributors, and users, resulting in the development and promulgation of 17 simplified practice recommendations, 48 preliminary conferences, and 29 revision conferences, resulting in the reaffirmation of 17 existing schedules and the revision of 12 recommendations, were held. Forty-four new fields requested cooperation in simplification programs.

A total of 898 acceptances of recommendations have been received from trade associations and other organized groups, as well as individual acceptances from 6,676 manufacturers, distributors, and users. Approximately 350,000 copies of simplified practice recommendations have been sold through the Government Printing Office. Judging from the number of foreign visitors and by the numerous requests received, there is a growing interest abroad in the simplification movement.

*American Marine Standards Committee.*—This committee is now composed of 324 member bodies, among which practically all phases

of the marine industry are represented. Technical activities are carried on by special committees, subject committees, and technical committees, comprising an aggregate personnel of about 270 members. The finished work so far accomplished consists of 47 standards which are being published as a series of the Department of Commerce.

*Automobile headlight standards.*—In addition to the testing of devices to determine whether they comply with the requirements of some of the States, the bureau has been called on to advise a number of State officials regarding the application of the uniform vehicle acts drawn up by the National Conference on Street and Highway Safety. It has also assisted in removing technical difficulties which have hindered the general use of the new types of headlights having controllable beams.

*Safety standards.*—Reports of the underwriters' laboratories on electrical devices were examined and advice given to State industrial commissions and local authorities on safety requirements. The bureau has assisted in revising the national electrical code of the National Fire Protection Association and in the preparation of final drafts of the lightning-protection code which has been under discussion for several years. Efforts have been continued to secure the general acceptance of a uniform code of colors for traffic signals.

*Dry-cell standardization.*—A complete new dry-cell testing equipment has been installed with a capacity of 4,000 batteries per year. Approximately 1,286 batteries from 20 manufacturers were included in the 1926 qualification tests made for the information of manufacturers and Government purchasing officers, and 1,240 batteries from 21 manufacturers have been started in the 1927 tests. New specifications for dry cells have been prepared and are now before the Federal Specifications Board and a sectional committee of the American Engineering Standards Committee for approval.

*Radio standardization.*—The bureau's representatives were active in the work of the American Engineering Standards Committee and the Institute of Radio Engineers in the standardization of radio-receiving sets and electron tubes. Special attention has been given to specific tube bases and tube terminology. The work on radio-receiving sets has led to the formulation of technical methods of measuring the most important characteristics of receiving sets.

*Handbook on optical design.*—The first of three parts of a handbook on optical design, intended to lead to standardized methods in the design of optical parts, has been published. This gives a complete treatment of the third order aberration equations, their method of application, and the general deductions regarding lens design which may be drawn from them. Detailed numerical examples are introduced in order to show clearly the method of using the equations and the great value of the results which may be obtained.

*Facilitating the use of specifications.*—Reference to work in connection with the "certification plan" and to the general work on specifications will be found under "General activities."

#### STANDARD MATERIALS (\$10,000)

*Distribution of standard samples.*—Standard samples comprising ores, ceramic materials, metallurgical products, and pure chemicals

were distributed. They are used to check chemicals and methods of analysis that control the manufacture and sale of metallurgical and agricultural products, to calibrate instruments, such as pyrometers and combustion bombs, and to further research. A direct result of their use is a saving of thousands of dollars a year through improved manufacturing operations and the avoidance of litigations based on faulty analysis.

#### INVESTIGATION OF RADIOACTIVE SUBSTANCES (\$9,540)

*Investigation of RaE.*—The correct value of the half period of RaE, one of the products in the radium disintegration series, has recently been the subject of some dispute in scientific circles. Therefore observations have been made on the rate of decay of several different preparations of RaE. The result of this investigation favors the earlier value of the half period; namely, 5 days, as contrasted with the currently accepted value of 4.85 days. The figures obtained for the different preparations range from 4.96 to 5.07.

*Tests of radium preparations.*—Over \$500,000 worth of radium preparations were tested. These tests determine the sale price of the preparations and prevent disputes.

#### INVESTIGATION OF AUTOMOTIVE ENGINES (\$25,000)

*Survey of methods of measuring antiknock characteristics of fuels.*—This project, which forms part of the cooperative fuel research program, is extremely important because of the present general interest in antiknock motor fuels and the lack of any accepted standard method of rating fuels on the basis of their antiknock characteristics. The recent action of the State of North Dakota, where a law was passed requiring that red antiknock gasolines must show "antiknock characteristics equal to a blend of 25 per cent benzol and 75 per cent straight-run gasoline from typical mid-continent crude oil or its equivalent," and stating that "the method used to determine whether a gasoline meets this requirement shall be the one adopted by the United States Bureau of Standards or recognized by said bureau as being the most satisfactory," has called attention to the fact that no entirely satisfactory method of rating antiknock motor fuels is yet available.

*Starting of internal-combustion engines.*—The engine-starting tests previously made on a four-cylinder truck engine were supplemented by tests on a six-cylinder passenger-car engine, and it was found that the starting performance of both engines on a given fuel was practically identical. A careful analysis of the engine tests on various fuels and of the volatility data on the same fuels led to the conclusion that the fuel requirements for engine starting could be specified in terms of the usual distillation curve of the American Society for Testing Materials.

*Phenomena of combustion.*—During the year further data were obtained on the velocities of explosive reactions at pressures less than atmospheric.

That reaction velocity is proportional to the molecular concentrations of the reacting gases has been verified for known mixtures of (1) carbon monoxide and methane with oxygen and (2) carbon

monoxide and hydrogen with oxygen. The effect of inert gases (nitrogen, helium, or carbon dioxide) on the carbon monoxide-oxygen reaction and on the methane-oxygen reaction has also been studied. These results are of great interest and importance to the mining and other industries.

*Economic volatility of motor fuels.*—The investigation of motor fuels with particular reference to their performance in automobile engines has been carried on for five years in cooperation with the American Petroleum Institute, the National Automobile Chamber of Commerce, and the Society of Automotive Engineers. During the past year the conclusions already reached have been published.

*Recommendations in regard to the purchasing of oils by the Federal Government.*—Evidence has been collected showing that in many instances unsatisfactory performance of oils has resulted simply from the selection of an oil of too high or too low viscosity. To remedy this, a "recommendation chart" has been prepared for Federal purchasing agents, indicating what grade (that is, viscosity) of motor oil is most suitable for use in the numerous different makes of passenger cars, trucks, and tractors.

*Cooperative investigation of lubricants for artillery automotive equipment.*—The bureau has cooperated with the Quartermaster Department of the Army in the examination of both new and used oils and in preparing a critical analysis of service tests of lubricants in artillery tractors at the Aberdeen Proving Ground.

*Automobile brakes and brake testing.*—The safety code for brakes and brake testing for which the bureau and the American Automobile Association were joint sponsors was approved in May by the American Engineering Standards Committee.

*Automotive headlighting.*—The bureau is cooperating with the Society of Automotive Engineers and the Illuminating Engineering Society in research work on the headlighting problem. Two test cars have been provided with sets of special equipment designed for testing on the road various headlighting combinations from the automobile driver's point of view, with the object of increasing the safety of night driving.

#### TRANSFERRED FUNDS (\$295,000)

*Organization and projects*—During the year funds were transferred from the following branches of the Government covering the projects listed:

Aeronautics Branch, Department of Commerce: Radio research, with special reference to radio in aeronautics.

Bureau of Engraving and Printing:

Increasing durability of paper currency.

Chromium plating of printing plates.

Bureau of Foreign and Domestic Commerce: Directory of commodity specifications.

Bureau of Mines: Petroleum research and testing.

Coast and Geodetic Survey: Special castings.

National Advisory Committee for Aeronautics:

Aerodynamical research.

Substitute for parachute silk.

Fatigue and embrittlement of duralumin.

## Navy Department:

- Rope and cordage.
- Storage batteries.
- General aeronautic power-plant problems.
- Gas-cell fabrics for dirigibles.
- Substitute for parachute silk.
- Corrosion of duralumin.
- Automatic mixture control for aircraft engines.
- Radiobeacons.
- Airship girders.
- Airplane carburetors.
- Making of optical glass.

Shipping Board: Miscellaneous problems in physics, chemistry, metallurgy, and engineering.

## War Department:

- Bomb ballistics.
- General automotive problems.
- Rope and cordage.
- Embrittlement of duralumin.
- Machine guns.
- Tests of aircraft engines in altitude laboratory.
- Sound tracking.
- Helium indicators.
- Precision gauges.

Many of these projects were supported partly by bureau and partly by transferred funds. The more important of these have already been described under the appropriate bureau fund.

Important accomplishments supported wholly by transferred funds include the following:

*Aircraft in commerce.*—The aeronautics branch of the Department of Commerce designated the Bureau of Standards as its research unit and gave special emphasis to research on the use of radio. Progress has been made in developing practical devices to serve as radio aids to air traffic. These devices include the directive radiobeacon, a system of marker beacons, and radiotelephony from ground stations to aircraft. The directive beacon was originally developed by this bureau in 1921 for the War Department, was further improved in subsequent years by that department, and has now undergone some additional development. This beacon sends out a directive type of radiation by means of which the aviator can follow a set course. The marker beacons are low-power radio transmitting outfits which are to be placed on the emergency landing fields and serve as milestones to indicate how far flight has progressed along the course marked out by the directive radiobeacon. The most immediately needed of these radio aids to air navigation is radiotelephony. By means of fixed ground stations it is expected that the Department of Commerce will be able to broadcast important weather information to airplanes in flight, and thus facilitate landing and navigation. The experimental work on radiotelephony included the connection of two-way conversations between airplane and ground to the regular telephone exchange, permitting conversations between persons at the ordinary desk telephones and other persons on airplanes in flight.

*Aerodynamical characteristics of airfoils at high speeds.*—A study of the aerodynamical characteristics of 21 airfoil sections at speeds up to and slightly above the speed of sound, made in cooperation with the National Advisory Committee for Aeronautics, indicates that the efficiency of any particular section is dependent upon the

speed employed. In order to secure maximum efficiencies in propellers, for example, the section should be modified near the tips of the blades by moving the maximum thickness of the section back toward the trailing edge. All sections which have been tested show decreased efficiency at the higher speeds which is associated with the change in the character of the flow around the airfoil.

*Airship girders.*—In cooperation with the Bureau of Aeronautics, Navy Department, investigation has been made of the deformation of the longitudinal elements of triangular and square girders. In the case of a girder 5 feet long, with longitudinal members of sheet duralumin formed into a channel section, it was found that the ultimate strength of the material could not be developed because the longitudinal members deformed by twisting about their longitudinal axes. By restraining this twist the strength of the girder was considerably increased. Probably girders with tubular longitudinals can be designed which will not fail before the compressive yield point of the material is reached. The strength of the girder would be increased about 50 per cent without increasing the weight, an important consideration in designing the structural framework of rigid dirigibles.

*Strength of tubes.*—In cooperation with the Bureau of Aeronautics, Navy Department, the strength of tubes of duralumin and alloy steel when used as columns or beams has been investigated. The work included determination of the strength of the tubes under axial compressive loads, transverse loads applied at the third points, and combinations of axial and transverse loading. An investigation of duralumin tubes 1.5 inches in diameter has been completed, and work is in progress on the remainder of the program.

*Prevention of embrittlement of duralumin.*—Duralumin is subject to intercrystalline corrosion resulting in embrittlement. The bureau has found that this corrosion is markedly reduced by rapid quenching in cold water during heat treatment, instead of in hot water or oil. Pure aluminum is not susceptible to this type of corrosion, and laboratory tests, supported by a year's exposure tests, indicate that a coating of pure aluminum effectively protects duralumin from intercrystalline attack. The method is now being used commercially. This work was supported by the War and Navy Departments and by the National Advisory Committee for Aeronautics.

*Substitute for goldbeater's skin.*—An important investigation on substitutes for goldbeater's skin for gas bags of dirigibles for the Navy Department was carried to the point at which experimental fabrics were made in a commercial coating plant instead of in pieces a yard square in the laboratory. Fabrics so made will be tried under service conditions. Many tests of permeability of airship fabrics to hydrogen were made.

*Helium purity indicators.*—Three helium purity indicators for airships were constructed, in addition to a special indicator capable of determining the purity of helium at four different points in the ship.

*Supercharging of aircraft engines.*—Tests have been made on a Curtiss D-12 engine and a Liberty 12 engine under ideal supercharging conditions; that is, with air supplied to the carburetor at sea-

level pressure while the pressure at the exhaust ports is reduced to the standard pressure corresponding to any desired altitude.

At the request of the Army Air Corps tests have been made of a Curtiss D-12 engine equipped with a gear-driven centrifugal supercharger installed between the carburetor and the intake manifold. This supercharger is designed for low altitude work and, for an engine speed of 2,000 r. p. m., its critical altitude is about 7,500 feet.

*Chromium plating.*—As a result of further studies of chromium plating the process at the Bureau of Engraving and Printing has been improved, and its use there has been extended to include both currency and stamp plates, with increased savings. The process is about to be installed at the Philadelphia Mint for plating dies, collars, and plaques. Tests indicate that this will improve the quality and decrease the cost of coinage. Experiments have also been made with promising results on specific applications of chromium plating for the War Department, Coast and Geodetic Survey, and National Advisory Committee for Aeronautics.

*Motor vehicle rating.*—This investigation, undertaken several years ago at the request of the State of Connecticut, had as its object the development of an equitable basis of rating motor vehicles for purposes of taxation. The particular problem has been solved in a manner simple enough to allow of economical administration, and a final report has been made.

#### GENERAL RECOMMENDATIONS

*Research on standards.*—A substantial increase in the salaries fund is urgently needed. This appropriation is used in the administrative and operative work of the bureau and also in carrying out certain of the functions enumerated in the organic act which are not otherwise provided for by Congress. These include the custody, comparison, and construction of standards used in scientific investigations, the determination of constants in physics, chemistry, technology and engineering, and the testing of standard measuring apparatus—all necessitating fundamental research. The importance of this work can not be too strongly emphasized. Additional assistance is needed to bring it more nearly current, as some of the basic standards have not been adequately checked for years. The visiting committee is strongly in favor of making more adequate provision for these fundamental functions to meet the ever-growing demands of the country for these services.

*Development of commercial standards.*—It is highly desirable to increase and consolidate our activities relating to standards used in commerce and industry by the formation of a division of commercial standards, extension to the commercial specification field of the cooperative methods of the division of simplified practice, and making more readily available to industry the results of the work of the Federal Specifications Board. A second assistant director should be placed in charge of this work, which is of the greatest economic importance to the country.

*Consolidation of funds.*—The 28 appropriations under which the bureau now operate necessitate the maintaining of records by the



accounting, auditing, and disbursing officials that could in part be dispensed with if the funds were consolidated. It is believed the appropriations of the bureau could be grouped into three or four classes, carrying the present items as subappropriations, without loss of administrative control of the various activities. This would permit the simplification of office procedure and eliminate technicalities that are occasioned by a multiplicity of funds.

*New heating and power plant.*—This summer actual construction work on the building will be started which it is expected will be completed next spring. Funds should be provided to cover the purchase and installation of the necessary operating equipment, amounting to \$300,000, of which one-third will be needed in each of the fiscal years 1928, 1929, and 1930.

*Hydraulic laboratory.*—I urgently recommend that authorization from Congress be obtained and funds be granted for the building and equipping of an hydraulic laboratory at the bureau. The functions of this laboratory would be to test hydraulic instruments and accessories, to study the behavior of moving water and the design of hydraulic structures, and to determine the fundamental data useful in hydraulic research and engineering, including problems relating to river and tide flow in various types of channels.

This is a most important field, and there are awaiting solution many fundamental problems which can only be attacked in a laboratory specially equipped for hydraulic research. At present there is no laboratory of this type in the country, while there are some 8 or 10 in Europe, where they have been found of the greatest use in the economical solution of complicated engineering problems involving flow of masses of water. In one European laboratory it is reported that the construction savings effected by each major problem there solved have paid the cost of the laboratory.

Such a laboratory would cost \$200,000, with \$50,000 a year for upkeep, and the several field services of the Government dealing with problems of water flow would benefit greatly.

*Need for increased facilities at branch laboratories.*—In order to take care of the many requests from governmental agencies for the testing of structural materials the bureau maintains three branch laboratories, located at Northampton, Pa.; Denver, Colo.; and San Francisco, Calif.

The work of the Northampton laboratory is exclusively cement testing, and as it is situated in the Lehigh Valley cement-producing district it supervises the major portion of Government orders for Bureau of Standards tested cement. The Denver laboratory cares for the cement testing of the territory between the Mississippi River and the Rocky Mountains. Besides its cement-testing work, many studies are made of the suitability of local aggregates for use in concrete structures for the Reclamation Service. The San Francisco laboratory cares for the cement testing on the west coast, which includes many shipments to the Hawaiian Islands, and also cares for many tests of miscellaneous materials used in construction work.

At the present time, with the large amount of work undertaken by the Government in various parts of the country, these branch laboratories are caring for a volume of work which prohibits further demands unless the personnel and equipment can be increased. With

the demand of purchasing agents that materials meet the requirements of the specifications of the Federal Specifications Board this commodity testing work will continue to increase, and it is in the interest of economy to make adequate provision for it.

*Medical aid.*—I again recommend that provision be made for the establishment at the bureau of a first-aid station in care of a competent physician preferably detailed from the Public Health Service. Such a station is an imperative need at an institution of the type of the bureau, where there are so many accident hazards. Also, there are several lines of work, including radium, X-ray and furnace operations, requiring medical oversight of the physical condition of the operating personnel.

Very truly yours,

GEORGE K. BURGESS,  
*Director, Bureau of Standards.*

## APPENDIX

### GENERAL FINANCIAL STATEMENT

During the fiscal year 1927 the bureau expended and accounted for funds aggregating \$2,475,280.48, including \$311,290.48 received by transfer and reimbursement from other departments for special researches.

The amounts and objects of each appropriation for the past fiscal year and two previous fiscal years, together with disbursements, unpaid orders outstanding, and unexpended balances for each appropriation, are shown in the following tables:

#### *Disbursements, liabilities, etc., 1927, 1926, and 1925 appropriations*

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1927				
Salaries.....	\$567,320.00	\$515,903.87	\$40,642.80	\$10,773.33
Equipment.....	88,000.00	75,024.45	11,309.99	1,665.56
General expenses.....	<sup>1</sup> 71,968.31	55,851.33	16,079.26	37.72
Improvement and care of grounds.....	12,000.00	10,532.36	1,280.35	187.29
Testing structural materials.....	<sup>2</sup> 233,186.12	200,437.09	28,817.58	3,931.45
Testing machines.....	38,000.00	32,270.06	5,520.91	209.03
Metallurgical research.....	43,140.00	38,386.32	4,254.04	499.64
Investigation of optical glass.....	20,520.00	17,269.11	2,519.24	731.65
Standard materials.....	10,000.00	9,307.36	564.72	127.92
Investigation of textiles.....	<sup>3</sup> 36,000.00	32,976.98	2,290.28	732.74
Sugar standardization.....	<sup>4</sup> 40,960.00	33,253.67	7,211.31	495.02
Gauge standardization.....	38,320.00	34,775.94	2,867.83	676.23
High-temperature investigation.....	9,740.00	7,369.69	2,077.38	292.93
Testing railroad scales.....	39,000.00	34,691.19	4,199.56	109.25
Investigation of fire-resisting properties.....	28,100.00	23,872.64	3,442.84	784.52
Testing miscellaneous materials.....	44,090.00	37,468.47	4,842.99	1,778.54
Investigation of public utility standards.....	100,000.00	87,549.30	11,642.89	807.81
Radio research.....	49,800.00	43,941.55	4,377.36	1,481.09
Industrial research.....	<sup>5</sup> 179,820.00	158,367.48	17,654.98	3,797.54
Sound investigation.....	10,580.00	9,588.71	490.33	500.96
Investigation of clay products.....	47,000.00	39,621.40	5,328.97	2,049.63
Color standardization.....	9,000.00	7,729.59	718.93	551.48
Investigation of radioactive substances.....	9,540.00	8,374.79	905.83	259.38
Standardizing mechanical appliances.....	<sup>6</sup> 28,215.00	24,219.36	2,588.59	1,407.05
Investigation of mine scales and cars.....	12,800.00	11,143.74	1,342.00	314.26
Standardization of equipment.....	<sup>7</sup> 116,000.86	93,037.63	16,959.63	6,003.60
Investigation of automotive engines.....	25,000.00	22,179.82	2,323.34	496.84
Sugar standardization (1926-27).....	25,000.00	22,775.84	1,577.56	646.60
Master track scale and test-car depot.....	50,000.00	135.53	49,777.44	87.03
Building for power plant.....	200,000.00	2,116.00	9,000.00	188,884.00
Appropriations transferred from other departments which are available for the current year:				
Compensation of employees, Bureau of Engraving and Printing.....	14,000.00	12,413.27	1,560.82	25.91
Export industries, Department of Commerce.....	4,500.00	4,355.60	-----	144.40
Advisory Committee for Aeronautics.....	34,000.00	30,549.73	3,382.37	67.90
Engineering, Bureau of Engineering.....	2,500.00	1,895.76	526.99	77.25
Automatic rifles (1927-28).....	2,000.00	1,066.01	445.56	488.43
Signal Service of the Army.....	1,800.00	1,407.94	358.33	3.73
Aircraft in commerce.....	94,500.00	56,702.57	37,244.03	553.40
Oil, gas, and oil shale investigation, Bureau of Mines.....	<sup>8</sup> 5,410.00	4,825.00	550.00	35.00
Aviation, Navy.....	81,900.00	65,016.30	16,254.01	629.69
Air Service of the Army.....	7,425.00	4,903.27	2,417.85	103.88
General expenses, Coast and Geodetic Survey.....	400.00	184.53	207.20	8.27
Incidental expenses of the Army.....	11,750.00	10,017.95	1,472.93	259.12
Ordnance stores ammunition (1927-28).....	1,000.00	-----	-----	1,000.00
Construction and repair, Bureau of Construction and Repair.....	1,750.00	1,557.25	186.34	6.41
Conference on oil pollution of navigable waters (1925-1927).....	<sup>9</sup> 2,482.19	1,911.75	364.83	205.61
Field Artillery armament.....	3,000.00	3,444.76	1,084.87	470.37

(Footnotes at end of table)

## Disbursements, liabilities, etc., 1927, 1926, and 1925 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
1927				
Air navigation facilities.....	\$1,613.00	\$1,613.00		
Appropriations transferred from other departments which are available for a period of two years:				
Ordnance and ordnance stores.....	13,400.00	9,199.76	\$1,665.97	\$2,534.27
Gauges, dies, and jigs, for manufacture.....	5,750.00	2,541.63	733.32	2,475.05
Air Service of the Army.....	1,000.00			1,000.00
<b>Total.....</b>	<b>2,475,280.48</b>	<b>1,903,777.35</b>	<b>331,094.35</b>	<b>240,408.78</b>
1926				
Salaries.....	<sup>10</sup> 516,760.00	516,487.24		272.76
Equipment.....	70,000.00	54,143.98	15,212.23	643.79
General expenses.....	<sup>11</sup> 45,568.74	41,693.76	859.14	3,015.84
Improvement and care of grounds.....	11,000.00	10,929.55		70.45
Testing structural materials.....	<sup>12</sup> 232,175.27	230,437.70	638.85	1,098.72
Testing machines.....	38,000.00	37,748.13	60.80	191.07
Metallurgical research.....	<sup>13</sup> 43,220.00	42,598.11	22.00	599.89
Investigation of optical glass.....	20,520.00	20,149.85	215.00	155.15
Standard materials.....	10,000.00	9,999.85		.15
Investigation of textiles.....	<sup>14</sup> 27,560.00	26,986.13	18.98	554.89
Sugar standardization.....	40,960.00	40,741.73		218.27
Gauge standardization.....	38,320.00	37,536.41	330.16	453.43
High temperature investigation.....	9,740.00	9,665.28	20.63	54.09
Testing railroad scales.....	39,000.00	38,664.51	73.06	262.43
Investigation of fire-resisting properties.....	28,100.00	27,907.86		192.14
Testing miscellaneous materials.....	<sup>16</sup> 49,090.00	48,933.71		156.29
Investigation of public-utility standards.....	100,000.00	99,282.82	288.64	428.54
Radio research.....	44,800.00	44,750.36	12.16	37.48
Industrial research.....	<sup>17</sup> 174,886.62	173,591.61	82.47	1,212.54
Sound investigation.....	<sup>18</sup> 5,655.00	5,606.52		48.48
Investigation of clay products.....	27,000.00	26,212.88	115.60	671.52
Color standardization.....	9,000.00	8,773.48	8.26	218.26
Investigation of radioactive substances.....	10,680.00	10,389.09		290.91
Standardizing mechanical appliances.....	27,800.00	27,699.95	13.15	86.90
Investigation of mine scales and cars.....	14,540.00	14,322.54	41.71	175.75
Standardization of equipment.....	<sup>19</sup> 111,634.00	110,423.15	220.29	990.56
Investigation of automotive engines.....	<sup>20</sup> 30,280.00	29,904.51	110.50	264.99
Appropriations transferred from other departments which are available for the current year:				
Compensation of employees, Bureau of Engraving and Printing.....	6,000.00	5,970.58		29.42
Signal Service of the Army.....	1,800.00	1,775.82		24.18
Automatic rifles (1926-27).....	2,000.00	1,970.23		29.77
Construction and repair, Bureau of Construction and Repair.....	5,750.00	5,487.75	95.06	167.19
General expenses, Bureau of Entomology.....	3,000.00	2,895.23		104.77
Advisory Committee for Aeronautics.....	32,600.00	31,835.84	453.52	310.64
Aviation, Navy.....	54,000.00	53,594.10	16.69	389.21
Export industries, Department of Commerce.....	4,500.00	4,336.08		163.92
Air Service of the Army.....	9,100.00	8,933.09		166.91
Incidental expenses of the Army.....	11,750.00	11,375.35		374.65
General expenses, Lighthouse Service.....	10,000.00	9,970.67		29.33
Engineering, Bureau of Engineering.....	2,500.00	2,424.55		75.45
Appropriations transferred from other departments which are available for a period of 2 years:				
Ordnance and ordnance stores.....	12,000.00	11,911.29	2.20	86.51
General expenses, Coast and Geodetic Survey.....	1,000.00		166.66	833.34
Gauges, dies, and jigs, for manufacture.....	2,750.00	1,860.54	416.66	472.80
Air Service of the Army.....	1,000.00		160.00	840.00
Signal Service of the Army.....	7,500.00	5,112.42	133.92	2,253.66
<b>Total.....</b>	<b>1,943,539.63</b>	<b>1,905,034.25</b>	<b>19,788.34</b>	<b>18,717.04</b>
1925				
Salaries.....	500,000.00	496,986.80	40.00	2,973.20
Equipment.....	71,000.00	70,605.98	5.30	388.72
General expenses.....	<sup>21</sup> 45,659.12	39,823.69	1,049.80	4,785.63
Improvement and care of grounds.....	11,460.00	11,297.00		163.00
Testing structural materials.....	<sup>22</sup> 252,317.22	247,330.23	163.86	4,823.13
Testing machines.....	39,460.00	39,359.82		100.18
Metallurgical research.....	<sup>23</sup> 44,513.18	44,313.71	33.20	166.27
Investigation of optical glass.....	25,000.00	24,923.52		76.48
Standard materials.....	10,000.00	9,974.13		25.87
Investigation of textiles.....	27,000.00	26,837.82		162.18
Sugar standardization.....	<sup>24</sup> 41,800.00	41,525.52		274.48
Gauge standardization.....	40,000.00	39,146.77		853.23
High-temperature investigation.....	10,000.00	9,987.64		12.36

(Footnotes at end of table)

## Disbursements, liabilities, etc., 1927, 1926, and 1925 appropriations—Continued

Appropriation	Total appropriation	Disbursements	Liabilities	Balance
Testing railroad scales.....	\$40,000.00	\$39,764.17	\$5.85	\$229.98
Investigation of fire-resisting properties.....	29,000.00	28,796.63		203.37
Testing miscellaneous materials.....	<sup>28</sup> 47,760.00	46,753.82		1,006.18
Investigation of public-utility standards.....	105,000.00	103,556.94	773.50	669.56
Radio research.....	<sup>28</sup> 46,320.16	46,240.50		79.66
Industrial research.....	<sup>27</sup> 177,013.58	174,765.55		2,248.03
Sound investigation.....	5,580.00	5,542.97		37.03
Investigation of clay products.....	<sup>28</sup> 30,200.00	29,984.57		215.43
Color standardization.....	10,000.00	9,799.14		200.86
Investigation of radioactive substances.....	11,000.00	10,932.12		67.88
Standardizing mechanical appliances.....	30,000.00	29,935.60		64.40
Investigation of mine scales and cars.....	15,000.00	14,633.54		366.46
Rope investigation.....	8,000.00	7,883.68		116.32
Standardization of equipment.....	110,000.00	109,764.26		235.74
Investigation of automotive engines.....	<sup>29</sup> 36,325.00	35,836.21		488.79
Land.....	173,117.00	173,117.00		
Appropriations transferred from other departments which were available during the fiscal year:				
Export industries, Department of Commerce.....	4,850.00	4,733.83		116.17
Aviation, Navy.....	34,000.00	33,271.89		728.11
Signal Service of the Army.....	3,800.00	3,646.17		153.83
Advisory Committee for Aeronautics.....	32,000.00	31,056.42		943.58
General expenses, Bureau of Entomology.....	5,000.00	4,927.57		72.43
Construction and repair, Bureau of Construction and Repair.....	10,500.00	10,437.57		62.43
Mineral mining, Bureau of Mines.....	5,000.00	4,666.22	19.80	313.98
Manufacture of arms (1924-25).....	950.00	943.12		6.88
Field artillery armament.....	950.00	947.84		2.16
Armament of fortification.....	950.00	865.18		84.82
Air Service of the Army.....	6,300.00	5,976.10		323.90
Incidental expenses.....	14,000.00	13,837.53		162.47
General expenses, Lighthouse Service.....	5,000.00	4,853.28	55.56	91.16
Conference on oil pollution of navigable waters (1925-26).....	<sup>30</sup> 8,000.00	5,517.81		2,482.19
Ordnance stores ammunition (1925-26).....	3,300.00	3,195.43		104.57
Washington-Alaska military cable and telegraph system (1925-26).....	2,000.00	1,936.66		63.34
Appropriations transferred from other departments which were available for a period of 2 years:				
Ordnance and ordnance stores.....	12,000.00	11,986.67	10.00	3.33
Construction and repair, Bureau of Construction and Repair.....	3,000.00	2,808.25		91.75
Automatic rifles (1924-25).....	2,000.00	1,991.26		8.74
Aviation, Navy.....	2,750.00	2,090.77	640.43	18.80
Air Service of the Army.....	1,750.00	1,746.28		3.72
Coast Guard.....	2,000.00	1,992.00		8.00
General expenses, Coast and Geodetic Survey.....	2,000.00	1,756.67		243.33
Proving grounds, Army.....	500.00	390.00		110.00
Engineering, Bureau of Engineering.....	2,000.00	1,898.75		101.25
Total.....	2,157,125.26	2,126,992.60	2,797.30	27,335.36

Includes reimbursements and transfers received from other departments and from the States of Oregon and Connecticut, as follows:

<sup>1</sup> \$3,613.31.	<sup>16</sup> \$5,000.
<sup>2</sup> \$3,186.12.	<sup>17</sup> \$766.62.
<sup>3</sup> \$1,000.	<sup>18</sup> \$75.
<sup>4</sup> \$2,800.	<sup>19</sup> \$1,634.
<sup>5</sup> \$5,700.	<sup>20</sup> \$5,280.
<sup>6</sup> \$415.	<sup>21</sup> \$1,159.12.
<sup>7</sup> \$1,000.86.	<sup>22</sup> \$17,257.22.
<sup>8</sup> \$1,395.	<sup>23</sup> \$513.18.
<sup>9</sup> This fund was reappropriated from the unincumbered balance of the 1926 appropriation.	<sup>24</sup> \$1,800.
<sup>10</sup> Includes supplemental appropriation of \$5,000.	<sup>25</sup> \$2,500.
<sup>11</sup> \$2,068.74.	<sup>26</sup> \$640.16.
<sup>12</sup> \$2,175.27.	<sup>27</sup> \$2,593.58.
<sup>13</sup> \$80.	<sup>28</sup> \$200.
<sup>14</sup> \$1,000.	<sup>29</sup> \$11,325.
<sup>15</sup> \$2,800.	<sup>30</sup> Unincumbered balance made available for 1927 by reappropriation.

Date	Description	Amount	Balance	Remarks
1862	...	...	...	...
1863	...	...	...	...
1864	...	...	...	...
1865	...	...	...	...
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1900	...	...	...	...

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